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THESIS

ANALYSIS OF AMPHIBIOUS SHIP LIFT CAPABILITY

by

Eric D. Williams

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Thesis Advisor: Samuel E. Buttrey

Second Reader: Ronald L. Brown

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Amphibious ship lift is crucial in supporting operations of Marine Air Ground Task Forces (MAGTF) for a wide range of conflicts. This thesis examines three different aspects of amphibious ship lift capability. First, gross lift capabilities of all amphibious ships in the Navy today are determined. Since some storage space on board a ship is required for access, tie-downs, and other considerations, the second step of this thesis is to use historical load-out data from six-month deployments to derive expected net lift capability from gross lift capability. A three-ship Amphibious Ready Group (ARG) is traditionally required to support a six-month MAGTF deployment. The final part of this thesis utilizes a linear program to determine specific ship combinations that optimize ARG lift capability for both the Pacific and Atlantic Fleets.

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ANALYSIS OF AMPHIBIOUS SHIP LIFT CAPABILITY

Eric D. Williams
Lieutenant, United States Navy
B.A., University of Illinois, 1992

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ABSTRACT

Amphibious ship lift is crucial in supporting operations of Marine Air Ground Task Forces (MAGTF) for a wide range of conflicts. This thesis examines three different aspects of amphibious ship lift capability. First, gross lift capabilities of all amphibious ships in the Navy today are determined. Since some storage space on board a ship is required for access, tie-downs, and other considerations, the second step of this thesis is to use historical load-out data from six-month deployments to derive expected net lift capability from gross lift capability. A three-ship Amphibious Ready Group (ARG) is traditionally required to support a six-month MAGTF deployment. The final part of this thesis utilizes a linear program to determine specific ship combinations that optimize ARG lift capability for both the Pacific and Atlantic Fleets.

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EXECUTIVE SUMMARY

Amphibious ship lift is crucial in supporting operations of Marine Air Ground Task Forces (MAGTF) for a wide range of conflicts. This thesis examines three different aspects of amphibious ship lift capability. First, gross lift capabilities of all amphibious ships in the Navy today are determined. Since some storage space on board a ship is required for access, tie-downs, and other considerations, the second step of this thesis is to use historical load-out data from six-month deployments to derive expected net lift capability from gross lift capability. A three-ship Amphibious Ready Group (ARG) is traditionally required to support a six-month MAGTF deployment. The final part of this thesis utilizes a linear program to determine specific ship combinations that optimize ARG lift capability for both the Pacific and Atlantic Fleets.

The gross capacities of all 42 amphibious ships are determined by collecting and comparing detailed information from different resources. These results are compiled in Appendix C, which is a valuable tool allowing ships within a class to compare their measured capacities. Load-out data is collected from different six-month deployments. This load-out data is used to calculate broken stowage factors for both vehicle and cargo stowage areas. Broken stowage factor is the percentage of gross capacity that is actually used for vehicle or cargo storage. Analysis of variance is used to compare broken stowage factors between classes of ships and two sample t-tests are used to compare broken stowage factors between fleets. Results show that statistically, there is no significant difference between ship classes or fleets, therefore they can all be described in one group. The resulting vehicle broken stowage factor is 0.70 and the resulting cargo broken stowage factor is 0.64. Load-out data is also used to determine average landing craft load-out. The average landing craft load-out for Landing Craft Air Cushions (LCACs) and Landing Craft Utilities (LCUs) are 985 and 1490 square feet respectively. The above information is then utilized to calculate net lift capacity for all 42 ships.

A linear programming model is utilized to determine the best combination of three ships for each ARG, mixing and matching LPDs and LSDs to the big decks in the schedule. The best combinations will be that ARG schedule with the greatest minimum ARG lift capacity in terms of base troop capacity, vehicle square footage, and cargo cubic footage. In other words the total ARG schedule is only as good as the lift capability of the ARG with the smallest capacity. Results show that their linear program provides negligible improvement for the Pacific Fleet. On the other hand, the Atlantic Fleet can be significantly improved by simply removing the Pensacola and the Portland from the ARG schedule.

I. INTRODUCTION

Amphibious ship lift is crucial in supporting operations of Marine Air Ground Task Forces (MAGTF) for a wide range of conflicts. This thesis examines three different aspects of amphibious ship lift capability. First, gross lift capabilities of all amphibious ships in the Navy today are determined. Since some storage space on board a ship is required for access, tie-downs, and other considerations, the second step of this thesis is to use historical load-out data from six-month deployments to derive expected net lift capability from gross lift capability. A three-ship Amphibious Ready Group (ARG) is traditionally required to support a six-month MAGTF deployment. The final part of this thesis utilizes a linear program to determine specific ship combinations that optimize ARG lift capability for both the Pacific and Atlantic Fleets.

II. BACKGROUND

A. DEPARTMENT OF THE NAVY LIFT STUDY

Approximately every ten years the Department of the Navy reviews amphibious lift requirements. The most recent study, Integrated Amphibious Operations and USMC Air Support Requirements (1990 DoN Lift) was completed in 1990. One of the many questions the DoN Lift Study asks is whether there is sufficient amphibious lift capability for two major regional conflicts. In an attempt to answer this question, the study compiled a table of "Gross Capacities of Ships and Class Averages" (Annex J of 1990 DoN Lift). Upon close review of this table, several problems are evident. First, the table appears to be generic in that vehicle storage capacity is reported as being constant within a class of ship. Furthermore data in the table is inaccurate since there have been many ship alterations since 1990. A current table is maintained by Combat Cargo Officers (CCOs) assigned to the staffs of the Commander, Naval Surface Forces U.S. Pacific Fleet (CNSP) and the Commander, Naval Surface Forces U.S. Atlantic Fleet (CNSL).

B. SHIP'S LOADING CHARACTERISTIC PAMPHLETS

While Annex J of the DoN Lift Study does not consider ship alterations or other deviations between ships in a class, such information is available from a Ship's Loading Characteristic Pamphlet (SLCP) that is maintained by each ship. The SLCP provides updated capacities for each compartment on the ship. It would be natural to assume that each ship can maintain its SLCP accurately. During research for this thesis, it became apparent that CCOs at the Commander Amphibious Group level (CPG-1, CPG-2, and CPG-3) and below strongly believe that the SLCP is consistently the most reliable source of capacity data. In contrast, interviewed CCOs and other personnel (at CNSL and

OPNAV N-85) above the Commander Amphibious Group level do not share this belief in SLCP accuracy. Therefore, this thesis will compile SLCPs and compare results with CNSL and CNSP ship capacity tables to generate an updated Gross Capacity of Ships and Class Averages table.

C. BROKEN STOWAGE FACTORS

" A broken stowage factor is applied to the available space for embarkation due to the loss between boxes, between vehicles, around stanchions, and over cargo. The factor will vary, depending on the type and size of vehicles, type and size of general cargo, training and experience of loading personnel, type of loading, method of stowage, and configuration of compartments." (Joint Pub 3-02.2) Usable space is also lost due to allowance for fire lanes, routine access, tie-downs used to secure cargo, and unit integrity in a combat load. The broken stowage factor is usually defined as the fraction of space used for storage, while broken stowage loss is the fraction of unusable space.

Broken stowage factors can be used to estimate net lift capability from gross lift capability. They are generally used for long-term planning of a mission prior to the generation of a load plan. In other words, broken stowage factors can be used to estimate how much cargo a platform can carry for an upcoming or a hypothetical deployment. In general, broken stowage factors are only for estimates of a ship's net lift capability. Once a ship's required cargo load has been determined, a detailed load plan designates the exact position of each piece of cargo.

The method for calculating broken stowage factors (BSF) is simple. The first equation is for calculating the broken stowage factor for a single cargo stowage area or for all cargo stowage areas in an entire ship.

$$Cargo\ BSF = \frac{Cargo\ Loaded\ (cubic\ footage)}{Total\ or\ Gross\ Capacity\ (cubic\ footage)}$$

The second equation is the method for calculating the vehicle broken stowage factor for a single vehicle stowage area. This equation should be used when vehicles stowed in the well deck are not being considered.

$$Vehicle\ BSF = \frac{Vehicles\ and\ Cargo\ Loaded\ (square\ footage)}{Total\ or\ Gross\ Capacity\ (square\ footage)}$$

"Each landing craft carried in amphibious ships has vehicle carrying capacity." (1990 DoN Lift) "Preboat load" refers to the vehicles loaded on those landing craft, measured in square feet. A third equation is the method for calculating the vehicle broken stowage factor for all vehicle stowage areas on an entire ship and accounts for the preboat load in the well deck. This method was used in Annex J of the 1990 DoN Lift Study and is used in the remainder of this thesis.

$$Vehicle\ BSF = \frac{Vehicles\ and\ Cargo\ Loaded\ (square\ footage)\ -\ Preboat\ Load\ (square\ footage)}{Total\ or\ Gross\ Capacity\ (square\ footage)}$$

According to Annex J of the DoN Lift study, a 0.70 broken stowage factor should be used for vehicle stowage areas, which are measured in square feet. For cargo stowage areas, which are measured in cubic feet, a broken stowage factor of 0.75 was specified. The main emphasis of this thesis is to derive accurate values of broken stowage factors from historical data from both fleets.

D. HISTORICAL DATA

Amphibious ship load-outs are generally largest during six-month deployments. Therefore, historical data used in this thesis was taken predominantly from six-month deployments that occurred during the past three years. Data is provided by each ship in the form of detailed load plans and Embarked Personnel Material Reports (EPMRs) which are examined to determine actual broken stowage factors.

E. AMPHIBIOUS READY GROUP (ARG) COMBINATIONS

Six-month deployments in both the Atlantic and the Pacific Fleets occur in the form of an Amphibious Ready Group (ARG). This ARG typically consists of three different ships. The largest ship, called the "big deck," is an LPH, LHA, or LHD. These ships resemble an aircraft carrier and carry the Aviation Combat Element (ACE). The second ship is an LPD, an amphibious transport dock, which serves as the primary control ship and also transports and lands Marines by landing craft or by helicopters. The third ship is an LSD, a dock landing ship also used to transport and land Marines. There are four different variations of LSDs. The Atlantic Fleet has eighteen amphibious ships available for six-month deployments: five big decks, five LPDs and eight LSDs. In the Pacific Fleet, CPG-3 has twelve amphibious ships available for six-month deployments: four big decks, four LPDs and four LSDs. At least one ARG from each fleet is always on station, which requires the oncoming ARG to depart prior to the return of the off-going ARG. Therefore, with six-month underway periods, one rotation through all the amphibious ships lasts almost two and one half years for the Atlantic Fleet and almost two years for the Pacific Fleet. A rotation is measured from the beginning of the first deployment until the completion of the last deployment, so that all ARGs are deployed once, and no ship is deployed more than once.

The ARG schedule is determined by factors other than ARG lift capability. The schedule for a single amphibious ship will include a significant maintenance period, a work-up period of approximately 9 months, and finally, the six-month deployment. Therefore, a change to the rotation of ships in the ARG schedule is both difficult and impractical. The purpose of the final portion of this thesis is to provide an alternative method for planning deployment schedules. A linear programming model is utilized to determine the best combination of three ships for each ARG, mixing and matching LPDs and LSDs to the big decks in the schedule. The best combinations will be that ARG schedule with the greatest minimum ARG lift capacity in terms of base troop capacity, vehicle square footage, and cargo cubic footage. In other words the total ARG schedule is only as good as the lift capability of the ARG with the smallest capacity.

This thesis proceeds as follows: Chapter III provides the gross capacities of ships and class averages and explains how these capacities were developed. Chapter IV explains the resources used for six-month load-outs. It explains the assumptions used and the calculations necessary to determine broken stowage factors. Chapter V analyzes the results of broken stowage factor calculations. It examines differences between fleets and classes of ships. It also reviews the Notional Landing Craft Load-out and Standard preboat load-out. Chapter VI describes the linear program model to determine the combinations of three ships that achieve the greatest minimum lift capability throughout the ARG schedule for both the Pacific and the Atlantic Fleets. Chapter VII summarizes the results and conclusions.

III. SHIP GROSS LIFT CAPACITIES

A. GROSS CAPACITIES OF SHIPS AND CLASS AVERAGES TABLE

The first step in calculating broken stowage factors is to determine accurate measures of total gross space available for each ship. Two such measures are routinely used: square footage and cubic footage available. Additional parameters are also collected to create a table similar to Annex J of the 1990 DoN Lift Study. The Gross Capacities of Ships and Class Averages Table (Appendix B) includes the following information:

1. Troop Bunks: Gross troop capacity in terms of base, surge and their combined total. Base is the total number of permanent troop bunks available.

2. Gross Vehicle Square Footage: “The entire deck area available for routine vehicle stowage excluding unacceptable areas and fire lanes.” (1990 DoN Lift) Square footage available within embarked landing craft is not included in this area.

3. Gross Cargo Cubic Footage: The available deck area multiplied by the allowable stowage height of the compartment. Allowable stowage height is the total height minus obstructions and the space required for proper sprinkler dispersion pattern as defined in the 1990 DoN Lift Study.

4. Bulk POL (petroleum, oils, and lubricants): The total bulk Diesel Fuel Marine (DFM), aviation fuel (JP-5), and motor gasoline (MOGAS) includes only internal tankage for both landing force and ship propulsion.

5. SLCP Approval Date: The signature date or date of validation for each SLCP.

B. DEVELOPMENT OF THE GROSS CAPACITIES OF SHIPS AND CLASS AVERAGES TABLE

Using the resources shown below, vehicle square footage and cargo cubic footage have been developed for each ship.

1. SLCPs obtained for 36 of 42 amphibious ships
2. Embarkation Lift Data from CNSL
3. Capacity of Pacific Fleet Amphibious Ships from CNSP
4. 1990 DoN Lift Study, Annex J

Capacity information provided by these resources is generally inconsistent. Appendix C summarizes the data provided (LST, LCC, and LPH class ships are not listed) including correct SLCP totals for each ship. Vehicle square footage is presented by compartment and cargo cubic footage is presented by cargo type to provide consistency for each class of ship.

Capacity estimates are refined by a thorough analysis to resolve the previously mentioned inconsistencies. In all cases, capacity data in the 1990 DoN Lift Study, Annex J, is outdated or incorrect. Consequently, capacity information from this resource is eliminated from further consideration. Sections I and VIII of each SLCP contain vehicle square footage and cargo cubic footage data. Section I provides Troop Cargo Capacities and Section VIII gives the Troop Cargo Space Capability Breakdown. While theoretically identical, totals from these two sections do not always agree with each other. Total capacities reported in some SLCPs include compartments or types of cargo that are omitted in other SLCPs of the same class of ship. Other inconsistencies are noted when comparing data reported in the SLCPs with data provided by CNSL or CNSP.

Using vehicle square footage and cargo cubic footage as the two measures of capacity for the 42 amphibious ships gives the 84 measures of capacity used in this study. On ten ships, both square footage and cubic footage from SLCP totals agree with capacities reported by CNS(P/L). On nine other ships, cubic footage from SLCP totals agree with capacities reported by CNS(P/L) while square footage reports disagree. On another four ships, square footage from SLCP totals agree with capacities reported by CNS(P/L) while cubic footage reports disagree. In three other instances, reported capacities differ by fewer than 20 units, which is taken to be negligible. For six ships, no SLCP is available and the CNS(P/L) data is assumed to be correct. Thus, of the 84 measures of capacity, 48 are considered to be known accurately.

The 36 remaining capacities require additional analysis to resolve disparities between SLCP totals and CNS(P/L) data. Several factors are considered in determining the correct capacity in these cases. For three entries, totals in the SLCP agree with capacities reported by CNS(P/L) even though individual entries in the SLCP do not add up to the reported total. Correlation between ships in a class is expected and can be exploited. Available Equipment Personnel Manning Reports (EPMRs) and resulting broken stowage factor calculations also help to determine the correct capacity (explained in Chapter IV). In many cases the smaller of the two capacities reported for a ship is discarded because it leads to an infeasible broken stowage factor. Troop bunks and bulk POL data is based primarily on SLCPs. Data from CNSP or CNSL is only used when the SLCP is not available.

IV. BROKEN STOWAGE FACTOR CALCULATIONS

A. EMBARKED PERSONNEL MATERIAL REPORTS

The correct way to calculate broken stowage factors is to know exactly what is stored in vehicle stowage spaces and what is stored in cargo stowage spaces, and then to divide the space used by the total or gross capacity. Unfortunately the location of vehicles and cargo is not always provided. This chapter explains the assumptions made to derive broken stowage factors using only the information from Embarked Personnel Material Reports (EPMRs) and a limited number of Detailed Load Plans.

Load-outs for six-month deployments are expected to be larger than other underway periods. Going back as far as three years, 31 EPMRs, exclusively from six-month deployments, were easily collected. However, since load plans are not consistently kept, only seven load plans were available for the above deployments. Of these seven, three load plans are incomplete because they do not include Landing Forces Operational Reserve Material (LFORM). One additional EPMR used from the Belleau Wood is not for a six-month deployment, but appears to be a full load-out. Using the Belleau Wood provides EPMRs for a total of four LHAs, two from each fleet, and increases the total sample size to 32.

EPMRs provide a good list of vehicle and cargo in terms of square footage and cubic footage, but they do not always list where that cargo is stowed (with the exception of vehicles loaded on landing craft). In seven EPMRs (without Detailed Load Plans) the information provided is detailed enough that an accurate location of vehicle and cargo can reasonably be determined. An EPMR contains six sections that describe the cargo load-out. Section D is the Lift Summary and should list all cargo in either square feet or cubic feet, or both. The primary cargo categories included in the Lift Summary are Aircraft (square footage), Vehicles (square footage), Outsized Cargo (square footage and cubic footage), Organizational Cargo (cubic footage) and LFORM (cubic footage). Aircraft are generally stowed in a hangar bay or on a flight deck and are not included in the broken stowage factor calculations. Section E is the Space Available, that is, the space remaining for more cargo after the load-out is complete. Space Available is listed for General Cargo, Ammunition, and Pyrotechnic areas in cubic feet and for the Flight Deck (when used for vehicle stowage), Well Deck, Vehicle, and Landing Craft stowage areas in square feet. Section G is the Organizational Recap and lists the organizations embarked together with each organization's aircraft, vehicles, outsized cargo, landing craft embarked, and vehicles loaded in the landing craft as well as a cargo summary. Section H is a description of LFORM broken down by class. Finally, Sections I and J describe other contingency assets (Other PWR Assets and the Opportune Lift).

A detailed spreadsheet (not attached) has been developed to ensure that the total space for vehicles, outsized cargo, organizational cargo, and LFORM listed in the Organizational Recap and LFORM sections matches the Lift Summary section. Generally it does match; however in a few instances data from the Organizational Recap or LFORM sections does not match those from the Lift Summary, so the larger totals are assumed to be more complete and correct. For the most part, Organizational Recaps from the Pacific Fleet include only numbers and descriptions of cargo loaded, and do not include square footage or cubic footage. Most outsized cargo is listed in both square footage and cubic footage, but there are some occasions where a small portion of outsized cargo or organizational cargo is listed in only one measurement. On those occasions the missing measurement is interpolated from outsized cargo for which both measures are provided. In almost all cases, outsized cargo and organizational cargo averaged 7.2 feet in height (that is, the ratio of volume to area averaged 7.2 feet). If, for example, only cubic footage is provided, then square footage is interpolated by dividing the cubic footage by 7.2 feet. The importance of outsized cargo and organizational cargo being represented in both area and volume will become apparent later in this chapter.

B. VEHICLE STOWAGE ASSUMPTIONS

The first assumption is that all vehicles are stowed in vehicle stowage areas. In most cases vehicles are not stowed in cargo stowage areas, so this is a very reasonable assumption. Vehicles are also reported stowed onboard landing craft as part of the preboat load. It should be noted that on six EPMRs, it is specifically reported that a small portion of either outsized cargo or organizational cargo is stored in vehicle stowage areas. That small portion of cargo is included in vehicle square footage totals.

C. CARGO STOWAGE

A natural assumption is that all outsized cargo is stored in vehicle storage areas and all remaining cargo is stored in cargo stowage areas. After reviewing the results in Table D.1 of Appendix D, however, this assumption proves to be untenable. In numerous cases, this would require that vehicle or cargo broken stowage factors exceed 1.0, and in a few cases approach 2.0. Of course a broken stowage factor greater than one is impossible. Conversely, several cargo broken stowage factors are extremely low. Additionally, the difference between vehicle and cargo broken stowage factors, which is expected to be small, can be in these cases as large as 1.548. With vehicle broken stowage factors exceeding 1.0, it is clear that at least a fraction of the outsized cargo is being stored in cargo storage areas. In other cases, with cargo broken stowage factors exceeding 1.0, it is clear that at least a fraction of non-outsized cargo is being stored in vehicle storage areas. The sizes of those fractions in some cases is unknown.

D. 6.9 PERCENT DIFFERENCE IN BROKEN STOWAGE FACTORS

The results from the eleven ships, four with complete Detailed Load Plans and seven with detailed EPMRs show that an average cargo broken stowage factor of 0.661 and an average vehicle broken stowage factor of 0.73, a difference of 0.069. Therefore, the next tentative assumption is that a vehicle broken stowage factor is always 0.069 larger than the cargo broken stowage factor on the same ship. The results of this assumption are displayed in Table D.2 of Appendix D. This assumption is too restrictive since a difference of 0.069 may not be valid for all ships. It does, however, provide a good starting point to compare a single artificial broken stowage factor between ships and to validate results.

In some cases, like that of the Wasp, a 6.9 percent difference (vehicle broken stowage greater than cargo broken stowage) could be achieved by assuming that a portion of outsized cargo was stored in vehicle storage areas and the remainder in cargo storage areas. (For the purpose of this analysis, cargo is categorized as either "outsized" or "regular." Regular cargo is defined as all cargo that is not outsized.) If a 6.9 percent difference is achievable with only outsized cargo, then all regular cargo is assumed to be stored in cargo storage areas. As a result, a value of zero is used for both Undesignated Cargo columns in Table D.2 of Appendix D. Otherwise, regular cargo will need to be considered to be stored in vehicle storage areas. ("Undesignated Cargo" gives the area of that regular cargo which might be stored in either location.) If for example, a 6.9 percent difference cannot be achieved with outsized cargo alone, as on the Ogden, a portion of regular cargo, either organizational cargo or LFORM, is assumed to have been stored in the vehicle storage areas. In these cases, the relevant volume of regular cargo has been subtracted from Regular Cargo and then listed in Undesignated Cargo of Table D.2 of Appendix D. Therefore, the sum of Regular Cargo and Undesignated Cargo on the cargo side of Appendix D, Table D.2, represents the total cubic footage of regular cargo. The value (in cubic feet) used for Undesignated Cargo in the cargo side of the table is also used in the Undesignated Cargo column on the vehicle side after conversion to square footage. Similarly, the value (in cubic footage) used for Outsized Cargo is also listed on the vehicle side, after conversion to square footage.

VEHICLE STOWAGE AREAS								
GROSS (Sqft)	VEHICLE LOADED	Vehicle Reported	Undesignated Cargo	Outsized Cargo	Space Available	Preboat Load-out	Vehicle - Preboat	Vehicle Brok Stow
15824	12172	8572	4611	2518	220	1504	10668	0.684

CARGO STOWAGE AREAS							% Cargo in Vehicle
GROSS (Cuft)	CARGO LOADED	Regular Cargo	Undesignated Cargo	Outsized Cargo	Space Available	Cargo Brok Stow	
48960	29819	6466	32718	14460	420	0.614	0.505

Table 4.1. USS Ponce (LPD-15) 6.9 Percent Difference in Broken Stowage Factors

The Ponce provides a good example of the above process (see Table 4.1 above). A total of 39,184 (6,466 + 32,718) cubic feet of regular cargo was loaded. If all of this regular cargo were to have been loaded in cargo stowage spaces, a 6.9 percent difference could not have been achieved. Therefore, it is assumed that a portion of that regular cargo, in this case 32,718 cubic feet, may have been stowed in vehicle stowage areas. Then 32,718 cubic feet is subtracted from the Regular Cargo column. The Regular Cargo column becomes 6,466 (39,184 – 32,718) cubic feet, which is assumed to have been stowed in cargo stowage areas. The 32,718 cubic feet now listed in the Undesignated

Cargo column on the cargo side measures approximately 4,611 square feet in area; that amount is listed in the Undesignated Cargo column on the vehicle side of the table. Similarly, 14,460 cubic feet of outsized cargo is equivalent to 2,518 square feet and it is this value that is listed in the Outsized Cargo column on the vehicle side.

Finally, the %Cargo in Vehicle column of Table 2 is the percentage of Undesignated Cargo and Outsized Cargo that must have been stowed in vehicle stowage areas to achieve a 6.9 percent difference between cargo and vehicle broken stowage factors. For example, on the Ponce, 50.5% of Undesignated Cargo and Outsized Cargo would have to have been stored in vehicle storage areas to achieve a 6.9 percent difference. Therefore the values for Undesignated Cargo and Outsized Cargo columns are multiplied by 0.505 on the vehicle square footage side. These products are added to the Vehicle Reported column to produce the Vehicle Loaded column (total square footage loaded in vehicle storage areas). In the case of the Ponce, 8,572 + 0.505 * (4,611 + 2,518) = 12,172 is the square feet of Vehicle Loaded. On the cargo side, the Undesignated Cargo and Outsized Cargo columns on the cargo cubic footage side are multiplied by 0.495 (1-0.505). The products are added to the Regular Cargo column to achieve the Cargo Loaded column (total cubic footage loaded in cargo storage areas). In the case of the Ponce, 6,466 + 0.495 * (32,718 + 14,460) = 29,819 is the cubic feet of Cargo Loaded. Therefore all cargo, both regular and outsized, has been included only once.

Four ships (Shreveport (97), Ashland, Carter Hall, and Oak Hill) are highlighted in Appendix D because their actual broken stowage factors are determined from detailed load plans. Seven ships (Wasp, Essex, Kearsarge, Peleliu, Guam(Oct 97), Austin, Ogden) are highlighted in Appendix D because the information in their EPMRs is detailed enough that an accurate location of vehicle and cargo can reasonably be determined. Even when all regular and outsized cargo on the Harpers Ferry is considered to have been stored in cargo storage areas, a 6.9 percent difference could not be achieved. Both broken stowage factors for the Fort Fisher greatly exceeded 1.0; therefore, it is assumed that the Fort Fisher's EPMR is incorrect and as a result, the Fort Fisher is excluded from the remaining portion of the analysis.

E. REDUCED RANGES

As stated previously, a problem with the 6.9 percent difference assumption is that it is too restrictive. Such an assumption implies that all ships have the same differences between cargo and vehicle broken stowage factors, which is unlikely. Returning to the original problem, it is known how much cargo is loaded on each ship. With the exception of eleven ships, the location of that cargo, however, is not known. In order to reduce the possible range of broken stowage factors and to better estimate the actual broken storage factor values, three new general assumptions are applied. The first of these assumptions is that all broken stowage factors are less than 0.95. The second is that all broken stowage factors are greater than 0.55. The last of these three assumptions is that the difference between broken stowage factors (ignoring sign) is less than 0.25.

The results of these three assumptions are shown on Table D.3 of appendix D. "Low %Cargo in Vehicle" is the lowest percentage of cargo that could be stored in vehicle stowage areas and still satisfy the three above assumptions. "High %Cargo in Vehicle" is the highest percentage of cargo that could be stowed in vehicle stowage areas and still satisfy the three above assumptions. The resulting reduced ranges are displayed in Figures D.4 and D.5 of Appendix D. This considerably reduces the possible range of vehicle broken stowage factors and slightly reduces the possible range of cargo broken stowage factors.

F. FINAL ASSUMPTIONS AND CALCULATIONS

The assumptions up to this point are all quite reasonable:

1. All vehicle square footage is assumed to be stowed in vehicle stowage areas.
2. A vehicle broken stowage factor 6.9 percent greater than cargo stowage factor is assumed to be achievable.
3. Broken stowage factors are assumed to be greater than 0.55 and less than 0.95.
4. The absolute difference between cargo broken stowage factors and vehicle stowage factors is assumed to be less than 0.25.

Under these assumptions, the vehicle broken stowage factor generally takes on a smaller range for each ship then does the cargo broken stowage factor. The results from the eleven ships with Detailed Load Plans or detailed EPMRs show that the average vehicle broken stowage factor is 0.73. It is then assumed that all ships carry vehicles of similar types and composition. Combined with the general knowledge that all ships use the same type of tie-downs to secure vehicles and do so in a similar manner, it appears reasonable to conclude that all vehicle broken stowage factors are nearly 0.73. The percent of cargo that must be stowed in vehicle stowage areas to achieve a vehicle broken stowage factor of 0.73 (or as close to 0.73 as possible) while still satisfying the four assumptions above is displayed in the "0.73 Vehicle" column in Table D.3, Appendix D. This approach produces several cargo broken stowage factors of either exactly 0.55 or 0.95. The final alternative value of percent cargo in vehicle stowage areas (for ships without detailed load plans) is developed by taking the average of percent cargo in vehicle stowage areas needed to achieve a vehicle broken storage factor of 0.73 or close to it (0.73 Vehicle) and the %Cargo in Vehicle from the 6.9 percent Difference Broken Stowage Factor Table (6.9 Percent).

$$\frac{[(0.73\,Vehicle)+(6.9\ Percent)]}{2} = Final\ \%\ Cargo\ in\ Vehicle\ Stowage\ Areas$$

The calculations to estimate actual %Cargo in Vehicle are displayed in Table D.3 of Appendix D. The final calculated broken stowage factors are in Table D.6 of Appendix D. Further evidence that these estimates are reasonable is seen in the small deviation of the average vehicle broken stowage factor from the results in the 6.9 percent difference table, a difference of only 0.004. These calculations in Table D.6 are considered to be the best estimate and are utilized for the remaining portion of this thesis.

V. ANALYSIS OF BROKEN STOWAGE FACTORS AND LOAD-OUTS

A. LANDING CRAFT

1. Notional Landing Craft Load-Out

"In order to calculate the amount of additional lift provided due to landing craft considerations, it is necessary to establish a notional boat plan." (1990 DoN Lift) In this context, a notional boat plan is the ideal number of landing craft loaded for each type of ship. In Annex J of the 1990 DoN Lift Study "this is accomplished by first loading Landing Craft Air Cushion (LCAC) to capacity in all potential LCAC-capable ships. The best fit of boats is then used to fill any remaining boat well space." The LCAC is clearly the landing craft of choice for over-the-horizon missions, "combining heavy lift capability of the surface assault with the high speeds of helicopterborne assault." (FMFRP 1-18)

1990 DoN Lift
Notional Landing Craft Load-out

	LCAC	LCU	LCM8
LHD	3		
LHA	1	2	1
LPH			
LPD-4	1		2
LSD-36	3		
LSD-36M	2		
LSD-41	4		
LSD-49	2		
LST			

This method of determining landing craft load-out is appropriate when planning for a single combat mission or amphibious assault. This was the reasoning applied according to Lieutenant Colonel Jeffrey M. Parkinson who was the Amphibious Requirements Officer at Headquarters U.S. Marine Corps just prior to publishing the 1990 DoN Lift Study. This table is not, however, appropriate when considering six-month deployments because six-month deployments generally include multiple missions or contingency plans. In addition, Landing Craft Mechanized (LCM-8) boats are rarely used. For the purpose of this thesis the following table reflects the notional landing craft load-out for a six-month deployment.

Six-Month Deployment
Notional Landing Craft Load-out

	LCAC	LCU
LHD	3	
LHA		4
LPH		
LPD-4		1
LSD-36	3	
LSD-36M	2	
LSD-41	4	
LSD-49	2	
LST		

This table reflects a typical load-out for six-month deployments. It is different from the 1990 Notional Landing Craft Load-out table only for the LHA and LPD-4 classes. It was developed using the 32 EPMRs discussed in Chapter IV and was confirmed by Major J. B. Scruggs, the Combat Cargo Officer for Commander, Amphibious Group Two.

2. Standard Preboat Load-Outs

a. Standard Landing Craft Air Cushion (LCAC) Preboat Load-Out

From the original sample set of 32 ship deployments, only ten were ships that embarked (loaded) LCACs. Out of those ten ships, only four provided the preboat load-out in square feet in their EPMR for a total of 13 LCACs. The following table lists this sample set of LCAC preboat load-outs (the three entries for the Kearsarge are from a single deployment but were listed individually in the EPMR):

LCAC PREBOAT LOAD-OUTS			
	Number Embarked	sqft	AVG Load-out
Kearsarge	1	839	839
Kearsarge	1	718	718
Kearsarge	1	733	733
Ashland	4	4197	1049
Pensacola	3	3148	1049
Wasp	3	3173	1058

Annex J of the DoN Lift Study states "the average square feet of vehicles preloaded in the high threat case is about 750 SQFT; in the mid and low cases, about 700 SQFT. A reasonable average load which accounts for variations in landing plans is 720 SQFT" (original emphasis). This average LCAC preboat load-out number is used to calculate net ship lift capacity. However, the LCAC sample set has a mean of 985 square feet with a 95-percent confidence interval of approximately +/– 78 square feet (assuming constant area for LCACs aboard a ship, with the exception of the Kearsarge) and is expected to more accurately represent the standard LCAC preboat load-out.

LCAC Preboat Load-Out Descriptive Statistics	
Mean	985
Standard Deviation	129
Range	340
Minimum	718
Maximum	1058
Count	13
Confidence Interval(95.0%)	78.2

b. Standard Landing Craft Utility (LCU) Preboat Load-Out

Sixteen amphibious ships from the original sample set of 32 EPMRs embarked LCUs. Out of those sixteen ships, twelve provided the preboat load-out in square footage for a total of 18 LCUs. The following table lists this sample set of LCU preboat load-outs (the four entries for the Saipan are from a single deployment but were listed individually in the EPMR):

LCU PREBOAT LOAD-OUTS			
	Number Embarked	sqft	AVG Load-out
Shreveport (97)	1	1521	1521
Ponce	1	1504	1504
Oak Hill	1	1415	1415
Saipan	1	1488	1488
Saipan	1	1482	1482
Saipan	1	1474	1474
Saipan	1	711	711
Nassau	4	3348	837
Trenton (Jan 98)	1	1348	1348
Trenton (Jan 96)	1	1369	1369
Carter Hall	1	1593	1593
Portland (Jan 98)	1	1426	1426
Portland (Jan 96)	1	1580	1580
Shreveport (Aug 95)	1	676	676
Austin	1	1654	1654

Annex J of the DoN Lift Study suggests that 1980 square feet is the standard preboat load-out for LCUs, and it uses this number to calculate ship net lift capacity. In contrast, the Amphibious Ships and Landing Craft Data Book (FMFRP 1-18) states that the cargo deck capacity for an LCU is 1850 square feet. The largest preboat load-out from the LCU sample set is 1654. This total sample set has a mean of 1255 square feet with a 95-percent confidence interval of approximately +/– 350 square feet (assuming constant area for LCUs aboard the Nassau). Six of the eighteen LCUs (33 percent) have a preboat load-out of less than 838 square feet. The remaining LCUs all have a preboat load-out greater than 1347 square feet. There is a considerable gap between these two groups. One reason for samples less than 838 square feet could be that these preboat load-outs allocate space for carrying troops. It is assumed that these two groups do not come from a common distribution. Therefore, the smaller preboat load-outs are omitted to ensure we are using only completely full LCUs. The remaining sample set has a mean of 1488 square feet with a 95-percent confidence interval of approximately +/- 58 square feet (assuming constant area for LCUs aboard the Nassau) and is expected to more accurately represent the standard LCU preboat load-out. The following table contains descriptive statistics for the LCU preboat load-out sample set.

LCU Preboat Load-out Descriptive Statistics	
Mean	1488
Standard Deviation	91
Range	306
Minimum	1348
Maximum	1654
Count	12
Confidence Interval(95.0%)	58

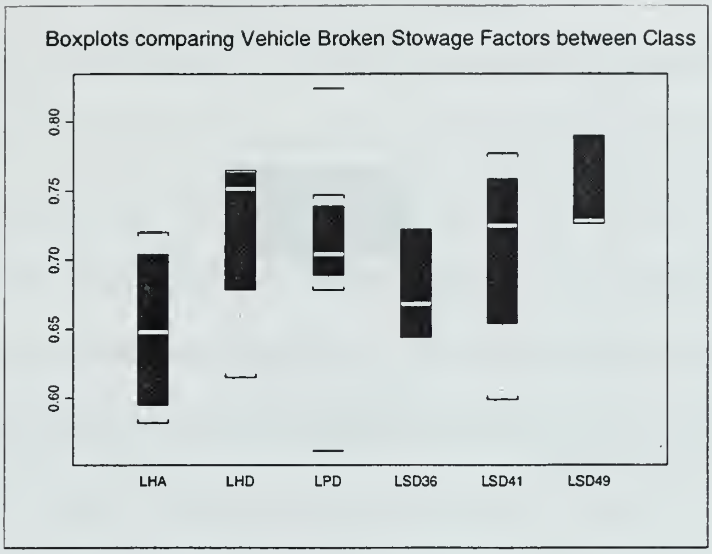
B. VEHICLE BROKEN STOWAGE FACTORS

1. Comparison Between Ship Classes

The following table lists in order of ship class, vehicle broken stowage factors from the data provided in Table D.6 of Appendix D. Data from the Guam has been excluded since the last LPH has been scheduled for decommissioning in 1998. Also given are rankings of the broken stowage factors from high to low.

Ship	Class	Vehicle Broken Stowage Factor	Rank (high to low)
Wasp	LHD	0.761	5
Essex	LHD	0.615	24
Kearsarge	LHD	0.742	7
Boxer	LHD	0.765	4
Saipan	LHA	0.720	14
Belleau Wood	LHA	0.582	27
Nassau	LHA	0.688	20
Peleliu	LHA	0.608	25
Austin	LPD	0.707	16
Ogden	LPD	0.824	1
Cleveland	LPD	0.562	28
Juneau	LPD	0.747	6
Shreveport (97)	LPD	0.689	19
Shreveport (Aug 95)	LPD	0.678	21
Nashville	LPD	0.701	17
Trenton (Jan 98)	LPD	0.733	10
Trenton (Jan 96)	LPD	0.739	9
Ponce	LPD	0.699	18
Portland (Jan 98)	LSD-36	0.722	13
Portland (Jan 96)	LSD-36	0.668	22
Pensacola	LSD-36	0.644	23
Whidbey Island	LSD-41	0.777	3
Comstock	LSD-41	0.599	26
Tortuga	LSD-41	0.740	8
Ashland	LSD-41	0.709	15
Harpers Ferry	LSD-49	0.726	12
Carter Hall	LSD-49	0.728	11
Oak Hill	LSD-49	0.790	2
La Moure County	LST	0.555	29

The La Moure County will be dismissed since one sample from the LST class is insufficient to accurately represent that class of ship. When determining if the remaining six classes can be grouped together it must be determined whether the vehicle broken stowage factors from the different classes behave like independent samples from a common distribution. The null hypothesis (H_o) is that the entire sample set is from a common distribution. The alternative hypothesis (H_1) then is that the entire sample set is not from a common distribution.



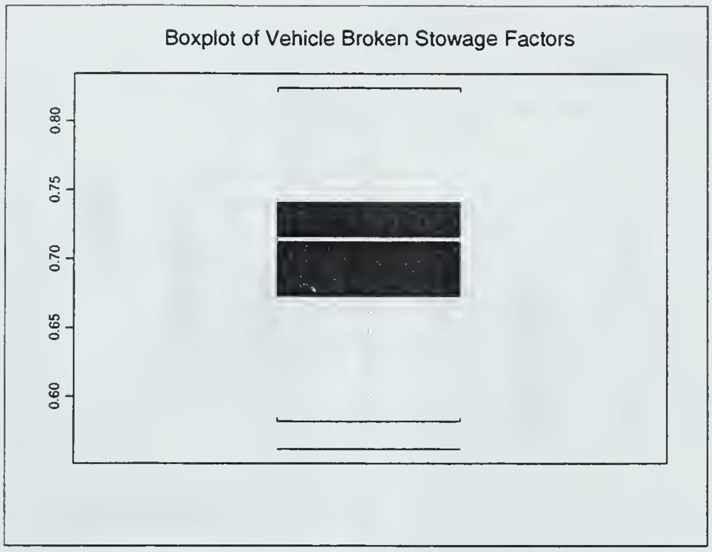
Analysis of Variance Table

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Class	*5*	*0.0209*	*0.0042*	*1.0150*	*0.4326*
Residuals	*22*	*0.0907*	*0.0041*		

An analysis of variance of these six classes with the usual assumptions (random samples from a normal population and constant variance) results in a p-value of 0.433. The null hypothesis (Ho) fails to be rejected; therefore the entire sample set is assumed to be from a common distribution. From the sample of 28 ships it has been determined that in order to predict vehicle broken stowage factors, all classes of ships can best be described in one single group. The mean vehicle broken stowage factor is estimated to be 0.702 with a 95-percent confidence interval of +/- 0.025.

Vehicle Broken Stowage Factor

Mean	0.702
Standard Deviation	0.064
Range	0.262
Minimum	0.562
Maximum	0.824
Count	28
Confidence Interval(95.0%)	0.025



The LST and LSD36M classes are not adequately represented in the sample set. However, it is expected that the LST and the LSD36M classes will behave like the other classes.

2. Comparision Between Fleets

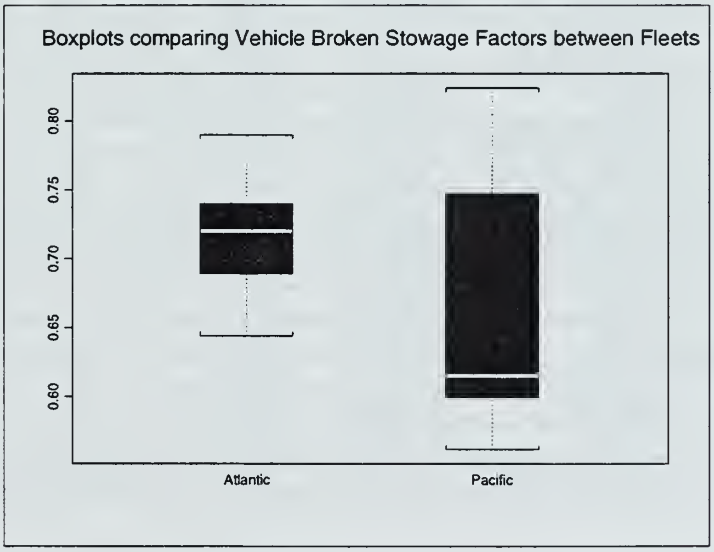
ATLANTIC FLEET		
Ship	Class	Vehicle Broken Stowage Factor
Wasp	LHD	0.761
Kearsarge	LHD	0.742
Saipan	LHA	0.720
Nassau	LHA	0.688
Austin	LPD	0.707
Shreveport (97)	LPD	0.689
Shreveport (Aug 95)	LPD	0.678
Nashville	LPD	0.701
Trenton (Jan 98)	LPD	0.733
Trenton (Jan 96)	LPD	0.739
Ponce	LPD	0.699
Portland (Jan 98)	LSD36	0.722
Portland (Jan 96)	LSD36	0.668
Pensacola	LSD36	0.644
Whidbey Island	LSD41	0.777
Tortuga	LSD41	0.740
Ashland	LSD41	0.709
Carter Hall	LSD49	0.728
Oak Hill	LSD49	0.790

PACIFIC FLEET		
Ship	Class	Vehicle Broken Stowage Factor
Essex	LHD	0.615
Boxer	LHD	0.765
Belleau Wood	LHA	0.582
Peleliu	LHA	0.608
Ogden	LPD	0.824
Cleveland	LPD	0.562
Juneau	LPD	0.747
Comstock	LSD41	0.599
Harpers Ferry	LSD49	0.726

In the sample sets above the Atlantic Fleet achieves a mean value of 0.718 and the Pacific Fleet achieves a mean value of 0.67. Since the variances of the underlying populations may not be identical, a Welch Modified Two-Sample t-Test is used. Comparing the mean values of the two fleets results in a p-value of 0.1841 (bigger than the usual critical value of .05). Therefore, assuming that the values represent random samples, it is not clear whether the population from which Atlantic Fleet data is drawn has a mean vehicle broken stowage factor higher than that of the Pacific Fleet. Boxplots of the two fleets are provided below:

```
              Welch Modified Two-Sample t-Test

t = 1.4368, df = 9.132, p-value = 0.1841
alternative hypothesis: true difference in means is not
equal to 0
95 percent confidence interval:
 -0.0273  0.1231
sample estimates:
 mean of x mean of y
  0.7179  0.67
```



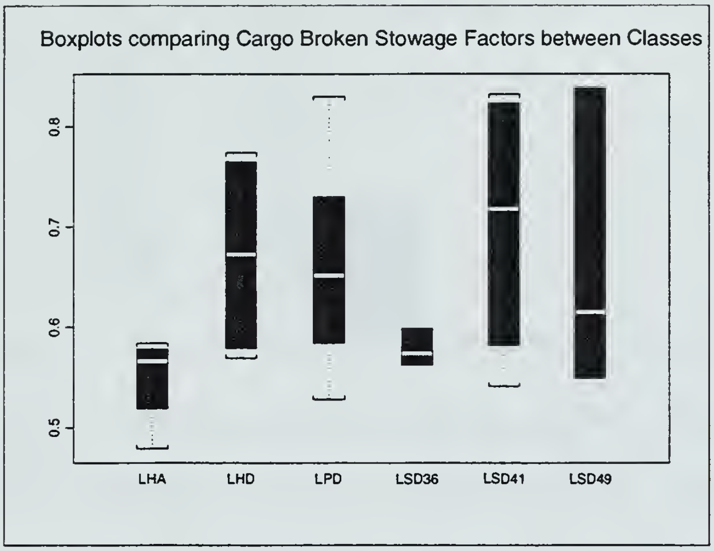
C. CARGO BROKEN STOWAGE FACTORS

1. Comparison Between Ship Classes

The following table lists in order of ship class, cargo broken stowage factors from the data provided in Table D.4 of Appendix D. Data from the Guam has been excluded since the last LPH has been scheduled for decommissioning in 1998. Also given are rankings of these cargo broken stowage factors from high to low.

Ship	Class	Cargo Broken Stowage Factor	Rank (high to low)
Wasp	LHD	0.589	16
Essex	LHD	0.569	22
Kearsarge	LHD	0.756	6
Boxer	LHD	0.774	5
Saipan	LHA	0.479	29
Belleau Wood	LHA	0.584	17
Nassau	LHA	0.573	21
Peleliu	LHA	0.559	21
Austin	LPD	0.732	7
Ogden	LPD	0.628	11
Cleveland	LPD	0.528	27
Juneau	LPD	0.730	8
Shreveport (97)	LPD	0.830	3
Shreveport (Aug 95)	LPD	0.595	15
Nashville	LPD	0.584	18
Trenton (Jan 98)	LPD	0.675	10
Trenton (Jan 96)	LPD	0.697	9
Ponce	LPD	0.582	19
Portland (Jan 98)	LSD36	0.599	14
Portland (Jan 96)	LSD36	0.574	20
Pensacola	LSD36	0.562	23
Whidbey Island	LSD41	0.832	2
Comstock	LSD41	0.541	26
Tortuga	LSD41	0.814	4
Ashland	LSD41	0.622	12
Harpers Ferry	LSD49	0.549	25
Carter Hall	LSD49	0.838	1
Oak Hill	LSD49	0.615	13
La Moure County	LST	0.517	28

The La Moure County will be dismissed since one sample from the LST class is insufficient to accurately represent that class of ship. Once again, when determining if the remaining six classes can be grouped together it must be determined whether the cargo broken stowage factors from different classes behave like independent samples from a common distribution. The null hypothesis (H_o) is that the entire sample set is from a common distribution. The alternative hypothesis (H_1) then is that the entire sample set is not from a common distribution.



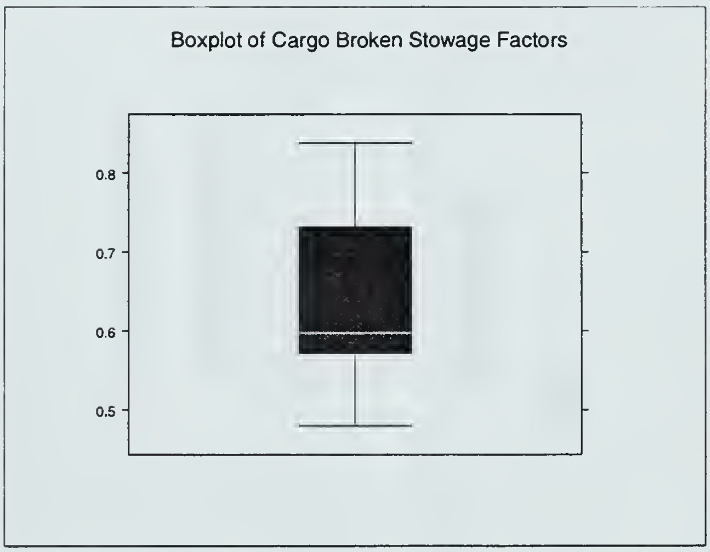
Analysis of Variance Table

	Df	Sum of Sq	Mean Sq	F Value	Pr(F)
Class	5	0.0696	0.0139	1.3588	0.2776
Residuals	22	0.2252	0.0102		

An analysis of variance of these six classes with the usual assumptions (random samples from a normal population and constant variance) results in a p-value of 0.278. The null hypothesis (Ho) fails to be rejected; therefore the entire sample set is assumed to be from a common distribution. From the sample of 28 ships it has been determined that in order to predict cargo broken stowage factors, all classes of ships can best be described by one single group. The mean cargo broken stowage factor is estimated to be 0.643 with a 95 percent confidence interval of +/- 0.041.

Cargo Broken Stowage Factor

Mean	0.643
Standard Deviation	0.105
Range	0.359
Minimum	0.479
Maximum	0.838
Count	28
Confidence Interval(95.0%)	0.041



The LST and LSD36M classes are not adequately represented in the sample set. However, it is expected that the LST and LSD36M classes will behave like the other classes.

2. Comparison Between Fleets

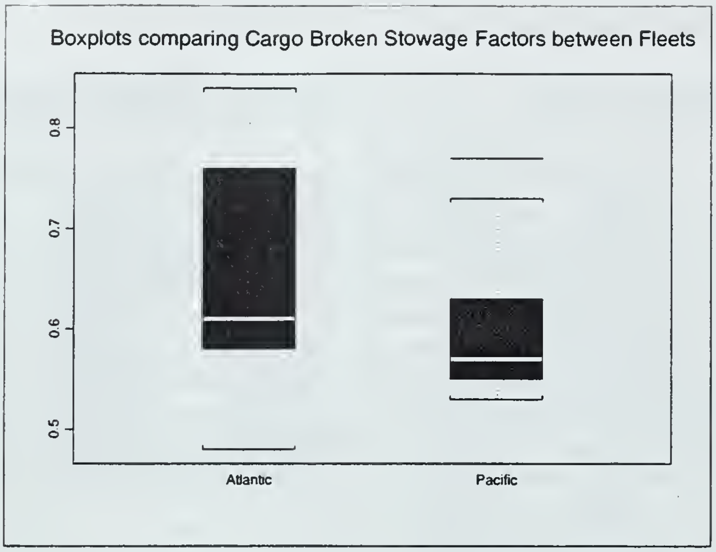
ATLANTIC FLEET		
Ship	Class	Cargo Broken Stowage Factor
Wasp	LHD	0.589
Kearsarge	LHD	0.756
Saipan	LHA	0.479
Nassau	LHA	0.573
Austin	LPD	0.732
Shreveport (97)	LPD	0.830
Shreveport (Aug 95)	LPD	0.595
Nashville	LPD	0.584
Trenton (Jan 98)	LPD	0.675
Trenton (Jan 96)	LPD	0.697
Ponce	LPD	0.582
Portland (Jan 98)	LSD36	0.599
Portland (Jan 96)	LSD36	0.574
Pensacola	LSD36	0.562
Whidbey Island	LSD41	0.832
Tortuga	LSD41	0.814
Ashland	LSD41	0.622
Carter Hall	LSD49	0.838
Oak Hill	LSD49	0.615

PACIFIC FLEET		
Ship	Class	Cargo Broken Stowage Factor
Essex	LHD	0.569
Boxer	LHD	0.774
Belleau Wood	LHA	0.584
Peleliu	LHA	0.559
Ogden	LPD	0.628
Cleveland	LPD	0.528
Juneau	LPD	0.730
Comstock	LSD41	0.541
Harpers Ferry	LSD49	0.549

In the sample sets above the Atlantic Fleet achieves a mean value of 0.66 and the Pacific Fleet achieves a mean value of 0.607. Since the variances of the underlying populations may not be identical, a Welch Modified Two-Sample t-Test is used. Comparing the mean values of the two fleets results in a p-value of 0.1845. Therefore, assuming that the values represent random samples, it is not clear whether the population from which the Atlantic Fleet data is drawn has a mean cargo broken stowage factor higher than that of the Pacific Fleet. Boxplots of the two fleets are provided below:

```
              Welch Modified Two-Sample t-Test

t = 1.375, df = 19.767, p-value = 0.1845
alternative hypothesis: true difference in means is not
equal to 0
95 percent confidence interval:
 -0.0274    0.1330
sample estimates:
 mean of x mean of y
  0.6595    0.6067
```



D. AMPHIBIOUS READY GROUP (ARG) LOAD-OUTS

There appears to be little gained by analyzing the load-outs of the ARGs as a group. There are no apparent trends in the amount of vehicle or cargo loaded or in broken stowage factors of ARGs. The table below provides the ships in each ARG, square feet of vehicle and cargo stowed in vehicle stowage areas (Vehicle Loaded), vehicle broken stowage factor (VBSF), cubic feet of cargo stowed in cargo stowage areas (Cargo Loaded), and the cargo broken stowage factor (CBSF) for each ship. Gunston Hall and Fort Fisher were not provided in the sample set, so the numbers from these two ships were interpolated using the averages for all LSDs. While most ARGs deploy with three ships, the Guam has regularly deployed with four ships in its ARG because the LPH class does not carry landing craft.

	Big Deck	Vehicle Loaded	VBSF	Cargo Loaded	CBSF	LPD	Vehicle Loaded	VBSF	Cargo Loaded	CBSF	LSD	Vehicle Loaded	VBSF	Cargo Loaded	CBSF
Jan-96	Guam	3177	0.787	38018	0.804	Trenton	12656	0.739	39442	0.697	Portland	12751	0.668	1250	0.574
											Tortuga	15842	0.740	5438	0.814
Jul-96	Saipan	24109	0.720	92093	0.479	Austin	12155	0.707	39257	0.732	Gunston	13994	0.712	15765	0.633
Oct-96	Essex	17790	0.615	82505	0.569	Clevela	9183	0.562	24594	0.528	Harpers	14165	0.726	38234	0.549
Dec-96	Nassau	22060	0.688	117604	0.573	Nashvil	15992	0.701	25869	0.584	Pensacol	10390	0.644	2541	0.562
Mar-97	Boxer	22251	0.765	112136	0.774	Ogden	11390	0.824	27643	0.628	Fort Fish	13994	0.712	15765	0.633
Apr-97	Kearsa	19378	0.742	126260	0.756	Ponce	12407	0.699	28262	0.582	Carter H	16975	0.728	24651	0.838
Aug-97	Peleliu	19487	0.608	88708	0.559	Juneau	10361	0.747	35614	0.730	Comstoc	13807	0.599	1654	0.541
Oct-97	Guam	2951	0.859	32908	0.715	Shrevep	12806	0.689	39384	0.830	Ashland	17731	0.709	4082	0.622
											Oak Hill	14409	0.790	39351	0.615
Jan-98	Wasp	20654	0.761	63537	0.589	Trenton	14376	0.733	38151	0.675	Portland	9467	0.722	1096	0.599
	AVG *	20818	0.700	97549	0.614	AVG	12370	0.711	33135	0.665	AVG	13994	0.712	15765	0.633

* AVG of Big Decks does not include Guam deployments

Each ARG is named after its big deck. In the table below, total ARG square feet of vehicle and cargo stowed in vehicle stowage areas (Total Vehicle) and total ARG cubic feet of cargo stowed in cargo stowage areas (Total Cargo) are provided for each ARG. The mean (AVG), standard deviation (STD DEV) and range for both vehicle broken stowage factors (VBSF), and the cargo broken stowage factors (CBSF) are provided for all ships in each ARG. The bottom of the table provides the mean (AVG), minimum (MIN) and (MAX) for each of these parameters for all ARGs.

	ARG	Total Vehicle	AVG VBSF	STD DEV VBSF	RANGE VBSF	Total Cargo	AVG CBSF	STD DEV CBSF	RANGE CBSF
Jan-96	Guam	44426	0.733	0.049	0.120	84147	0.722	0.112	0.241
Jul-96	Saipan	50258	0.713	0.007	0.013	147115	0.615	0.127	0.253
Oct-96	Essex	41138	0.634	0.084	0.164	145333	0.549	0.021	0.041
Dec-96	Nassau	48442	0.678	0.030	0.056	146014	0.573	0.011	0.022
Mar-97	Boxer	47636	0.767	0.056	0.112	155543	0.678	0.083	0.145
Apr-97	Kearsarge	48760	0.723	0.022	0.043	179173	0.726	0.131	0.256
Aug-97	Peleliu	43655	0.651	0.083	0.147	125976	0.610	0.105	0.189
Oct-97	Guam	47897	0.762	0.078	0.170	115725	0.695	0.101	0.215
Jan-98	Wasp	44497	0.739	0.020	0.039	102784	0.621	0.047	0.086
	AVG	46301	0.711	0.048	0.096	133534	0.643	0.082	0.161
	MIN	41138	0.634	0.007	0.013	84147	0.549	0.011	0.022
	MAX	50258	0.767	0.084	0.170	179173	0.726	0.131	0.256

VI. DETERMINING AMPHIBIOUS READY GROUPS (ARGs)

A. SCHEDULING DISCLAIMER

In both the Atlantic and Pacific Fleets an ARG is deployed for six-months at a time. An ARG traditionally consists of three ships: one big deck (LHA or LHD), one LPD, and one LSD. An ARG is generally always on station (Atlantic Fleet in the Mediterranean and the Pacific Fleet in the Western Pacific), which requires the oncoming ARG to arrive on station prior to the off-going ARG's departure. The schedule for a single amphibious ship may include a significant maintenance period, a work-up period of approximately 9 months, and finally, the six-month deployment in an ARG. Unplanned vacancies in the ARG schedule are generally filled by determining which amphibious ship is furthest along in its schedule and most ready for a six-month deployment. Therefore, it is conceded that the primary consideration in determining ARG schedules is not lift capability and that a change to the ARG schedule is extremely difficult and impractical. For purposes of this chapter, the number of schedule changes required to implement a proposed schedule is disregarded.

B. WORST-CASE LIFT CAPACITY

This chapter provides an example of scheduling using a linear programming model. It examines the possible benefits of creating an ARG schedule based primarily on lift capacity. The measure of effectiveness is "worst-case ARG lift capacity": an ARG schedule is assumed to be only as good as the ARG with the smallest lift capacity. The best schedule is therefore the schedule providing the greatest minimum (i.e., best worst-case) ARG lift capacity. Lift capacity is measured in terms of base troop capacity, net vehicle square footage, and net cargo cubic footage. The capacities used are explained in

Chapter VII and provided in the Net Capacities of Ships and Class Averages Table in Appendix E. It is assumed that each ARG requires one big deck, one LPD, and one LSD.

C. LINEAR PROGRAM MODEL

A mixed integer linear programming model is utilized to determine the best combinations of three ships for each ARG by mixing and matching LPDs and LSDs to the big decks in the schedule. This section defines requisite sets and indices, data elements, and decision variables and is followed by the model formulation.

Sets and Indices

i Type of Amphibious Ship (e.g., Big Deck, LPD, or LSD);

j Individual Amphibious Ship available for ARG schedule (e.g., Essex, Denver, Comstock,...);

k ARG designation (e.g., 1, 2, 3,...);

Data (Units)

$Troop_{ij}$ Troop base capacity for ship j of type i (troops);

$Vehicle_{ij}$ Net vehicle capacity for ship j of type i (square feet);

$Cargo_{ij}$ Net cargo capacity for ship j of type i (cubic feet);

P_{ijk} Existing schedule, two when ship j of type Big Deck was assigned to ARG k, one when ship j of type LPD or LSD was assigned to ARG k, zero otherwise;

Decision Variables (Units)

X_{ijk} Proposed schedule, one when ship j of type i is assigned to ARG k, zero otherwise;

WT Worst-case base troop capacity of all ARGs in proposed schedule (troops);

WV Worst-case net vehicle capacity of all ARGs in proposed schedule (square feet);

WC Worst-case net cargo capacity of all ARGs in proposed schedule (cubic feet);

Formulation

$$MAX \quad WT + WV /(\sum_i \sum_j Vehicle_{ij} / \sum_i \sum_j Troop_{ij}) + WC /(\sum_i \sum_j Cargo_{ij} / \sum_i \sum_j Troop_{ij})$$
$$+ \sum_i \sum_j \sum_k X_{ijk} P_{ijk} \qquad (1)$$

Subject To:

$$\sum_i \sum_j X_{ijk} Troop_{ij} \geq WT \quad \forall k . \qquad (2)$$

$$\sum_i \sum_j X_{ijk} Vehicle_{ij} \geq WV \quad \forall k . \qquad (3)$$

$$\sum_i \sum_j X_{ijk} Cargo_{ij} \geq WC \quad \forall k . \qquad (4)$$

$$\sum_i \sum_k Xijk \leq 1 \quad \forall j . \qquad (5)$$

$$\sum_j Xijk \leq 1 \quad \forall i,k . \qquad (6)$$

Constraint (2) measures the worst-case or smallest base troop capacity of all the ARGs in the schedule. Constraint (3) measures the worst-case or smallest net vehicle capacity of all the ARGs in the schedule. Constraint (4) measures the worst-case or smallest net cargo capacity of all the ARGs in the schedule.

Constraint (5) ensures each ship is scheduled at most once. Constraint (6) ensures that each ARG has at most one ship of each type.

The objective function (1) consists of four different terms. The first three terms simultaneously maximize the worst-case base troop capacity (WT), worst-case net vehicle capacity (WV), and the worst-case net cargo capacity (WC). Dividing WV by (sum of net vehicle capacity/sum of net troop capacity) and dividing WC by (sum of net cargo capacity/sum of net troop capacity) converts these terms to troop equivalent units and it also scales all three terms so they are equally important. In this format the model will raise WT, WV, and WC to their maximum but one of these may dominate one or both of the others. If one of these lift capacities is determined to be more important by the user, then that lift capacity can be multiplied in the objective function by a coefficient larger than one (a coefficient of three is suggested) and the selected lift capacity will dominate the other two.

The fourth term of the objective function (1), the sum of $X_{ijk}P_{ijk}$ provides a negligible value and is used only as a tiebreaker. When this term is "large" it means that schedule changes are fewest. Without this term there may be more than one resulting ARG schedule that provides the same maximum objective value. Therefore, if there is more than one possible answer, the fourth term of the objective function selects the ARG schedule with the fewest changes from the existing schedule. Also, as a result, all ships of one type remain in the same ARG as in the existing schedule. To ensure that all big decks (instead of LPDs or LSDs) remain in the same ARG as in the existing schedule, P_{ijk} is a value of two (instead of one) for ship j of type Big Deck when it was assigned to ARG k in the existing schedule and zero otherwise.

D. PROPOSED AMPHIBIOUS READY GROUPS

1. Pacific Fleet Results

CPG-3 presently has twelve amphibious ships available for ARGs in six-month deployments: four big decks, four LPDs and four LSDs. The following are the results of the model (without lift capacity coefficients) compared to the existing ARG schedule;

AMPHIBIOUS READY GROUPS TO OPTIMIZE WORST-CASE LIFT CAPACITY

EXISTING ARG SCHEDULE			
	Base Troops	NET Vehicles	NET Cargo
Essex	1631	20603	92767
Cleveland	659	11361	29821
Harpers Ferry	405	13944	50386
	2695	45908	172974
Boxer	1688	20603	92767
Ogden	724	11560	32751
Pearl Harbor	406	18770	43520
	2818	50934	169038
Peleliu	1903	23686	101649
Juneau	682	11203	31221
Comstock	402	17287	4305
	2987	52176	137176
Tarawa	1895	23384	101649
Denver	673	13208	36387
Mount Vernon	299	14555	1303
	2867	51147	139339
ARG AVG	2842	50041	154632
STD DEV	121	2808	18996
MINIMUM	2695	45908	137176

PROPOSED ARG SCHEDULE			
	Base Troops	NET Vehicles	NET Cargo
Essex	1631	20603	92767
Ogden	724	11560	32751
Pearl Harbor	406	18770	43520
	2761	50934	169038
Boxer	1688	20603	92767
Denver	673	13208	36387
Comstock	402	17287	4305
	2763	51098	133459
Peleliu	1903	23686	101649
Cleveland	659	11361	29821
Harpers Ferry	405	13944	50386
	2967	48991	181857
Tarawa	1895	23384	101649
Juneau	682	11203	31221
Mount Vernon	299	14555	1303
	2876	49142	134173
ARG AVG	2842	50041	154632
STD DEV	99	1129	24601
MINIMUM	2761	48991	133459
WORST CASE IMPROVEMENT	2.45%	6.71%	-2.71%
OVERALL IMPROVEMENT	2.15%		

While the worst-case net vehicle capacity and worst-case base troop capacity were improved, the worst-case net cargo capacity went down. In this case, net cargo capacity was dominated by the other two lift capacities. An overall improvement of only 2.15% is not expected to justify disruptions to the current ARG schedule. If however, the net vehicle capacity or base troop capacity is insufficient in the existing Essex ARG then the proposed schedule will provide the most overall improvement.

If only one lift capacity is important to the user, then the best possible worst-case result for that lift capacity has been determined. Each lift capacity is maximized one at a time, and the results are provided in the table below in the individual best column. All three individual best results cannot be achieved at one time.

	WT	WV	WC
Individual Best	2761	49450	138706

Since, in the original model without coefficients, the worst-case cargo capacity (WC) was reduced, a solution increasing WC is provided. The final model considers the possibility that WC is more important than the other two lift capacities, and WV is more important than WT. To achieve this hierarchy, the coefficients of 0.5, 1.0, and 3.0 are used in the following objective function and the results of the model are provided below.

$$MAX \quad (.5)WT + WV/(\sum_i \sum_j Vehicle_{ij} / \sum_i \sum_j Troop_{ij}) + (3)WC/(\sum_i \sum_j Cargo_{ij} / \sum_i \sum_j Troop_{ij}) + \sum_i \sum_j \sum_k X_{ijk} P_{ijk}$$

AMPHIBIOUS READY GROUPS TO OPTIMIZE WORST-CASE LIFT CAPACITY WITH ONLY POSITIVE IMPROVEMENT

OLD ARG SCHEDULE			
	Base Troops	NET Vehicles	NET Cargo
Essex	1631	20603	92767
Cleveland	659	11361	29821
Harpers Ferry	405	13944	50386
	2695	45908	172974
Boxer	1688	20603	92767
Ogden	724	11560	32751
Pearl Harbor	406	18770	43520
	2818	50934	169038
Peleliu	1903	23686	101649
Juneau	682	11203	31221
Comstock	402	17287	4305
	2987	52176	137176
Tarawa	1895	23384	101649
Denver	673	13208	36387
Mount Vernon	299	14555	1303
	2867	51147	139339
ARG AVG	2842	50041	154632
STD DEV	121	2808	18996
MINIMUM	2695	45908	137176

PROPOSED ARG SCHEDULE			
	Base Troops	NET Vehicles	NET Cargo
Essex	1631	20603	92767
Juneau	682	11203	31221
Pearl Harbor	406	18770	43520
	2719	50577	167508
Boxer	1688	20603	92767
Cleveland	659	11361	29821
Harpers Ferry	405	13944	50386
	2752	45908	172974
Peleliu	1903	23686	101649
Ogden	724	11560	32751
Comstock	402	17287	4305
	3029	52533	138706
Tarawa	1895	23384	101649
Denver	673	13208	36387
Mount Vernon	299	14555	1303
	2867	51147	139339
ARG AVG	2842	50041	154632
STD DEV	140	2875	18164
MINIMUM	2719	45908	138706

WORST CASE IMPROVEMENT	0.89%	0.00%	1.12%
OVERALL IMPROVEMENT	0.67%		

Once again the improvement is negligible. As long as the existing schedule meets the lift requirements of an ARG six-month deployment, then this small improvement does not justify disruptions to the current ARG schedule. If however, the net cargo capacity of 137,176 cubic feet is insufficient for the Peleliu ARG then the proposed schedule will provide the best possible improvement.

In addition, using the model has demonstrated that both WV and WC cannot both be simultaneously improved from the existing schedule. If improving one, the best that can be done with the other is to maintain the status quo.

The table below provides a summary of results in this section for the Pacific Fleet (CPG-3); the existing schedule, results from both models, and the individual best for each lift capacity.

	WT	WV	WC
Existing Schedule	2695	45905	137176
Model without Coefficients	2761	48991	133459
Individual Best	2761	49450	138706
Model with Coefficients	2719	45908	138706

2. Atlantic Fleet Results

CPG-2 presently has eighteen amphibious ships available for ARGs in six-month deployments: five big decks, five LPDs and eight LSDs. With more LSDs than any other type of ship, the question arises of how to best utilize all the LSDs. Historically, big deck and LPD combinations have remained the same in a five-ARG rotation, while LSD assignments have fluctuated due to their greater numbers and longer interdeployment periods. The rotation for the LSDs is not consistent since LSDs are sometimes used for a UNITAS six-month deployment. When the model is used for these eighteen ships it will choose the five LSDs that will provide the best results; three LSDs will not be utilized.

a. Two Ship Combinations

It is first assumed that CPG-2 wishes to continue to rotate all LSDs in the ARG schedule. The logical use of the model then is to determine the Big Deck and LPD combinations that achieve the best results, and let the LSDs fall where they may in their rotation. For purposes of comparison a typical schedule was used.

BIG DECK - LPD COMBINATIONS TO OPTIMIZE WORST-CASE LIFT CAPACITY

TYPICAL ARG SCHEDULE					PROPOSED ARG SCHEDULE			
	Base	NET	NET			Base	NET	NET
	Troops	Vehicles	Cargo			Troops	Vehicles	Cargo
Nassau	1903	27189	133396		Nassau	1903	27189	133396
Nashville	659	13105	30809		Nashville	659	13105	30809
	2562	40294	164205			2562	40294	164205
Kearsarge	1894	21546	106820		Kearsarge	1894	21546	106820
Ponce	728	12567	31334		Ponce	728	12567	31334
	2622	34112	138154			2622	34112	138154
Bataan	1737	21297	93423		Bataan	1737	21297	93423
Shreveport	665	12956	30365		Austin	727	11884	34334
	2402	34253	123788			2464	33181	127757
Wasp	1894	19763	92767		Wasp	1894	19763	92767
Trenton	721	13930	36195		Trenton	721	13930	36195
	2615	33694	128962			2615	33694	128962
Saipan	1904	27189	124627		Saipan	1904	27189	124627
Austin	727	11884	34334		Shreveport	665	12956	30365
	2631	39073	158961			2569	40145	154991
ARG AVG	2566	36285	142814		ARG AVG	2566	36285	142814
STD DEV	96	3139	17985		STD DEV	73	3338	16939
MINIMUM	2402	33694	123788		MINIMUM	2464	33181	127757

WORST-CASE IMPROVEMENT	2.58%	-1.52%	3.21%
OVERALL IMPROVEMENT	1.42%		

While the worst-case net cargo capacity and worst-case troop capacity were improved, the worst-case net vehicle capacity went down. In this case, net vehicle capacity was dominated by the other two lift capacities. An overall improvement of only 1.42% is not expected to justify disruptions to the current ARG schedule. If however, the net cargo capacity or base troop capacity in the current schedule is insufficient, then the proposed schedule will provide the most overall improvement.

Net cargo capacity and net troop capacity in the proposed schedule is the best that can possibly be achieved. In a second attempt, using a coefficient of three with WV in the objective function ensures that net vehicle capacity dominates and the following results can be achieved. These results are only a slight improvement from the typical schedule. The only difference from the typical schedule is that the Shreveport will deploy with the Kearsarge and the Ponce will deploy with the Bataan.

	WT	WV	WC
WV Dominating	2465	33694	124757
Improvement	2.62%	0.00%	0.78%
Overall Improvement	1.14%		

b. FIFTEEN SHIP AMPHIBIOUS READY GROUP SCHEDULE

If CPG-2 desires to choose only the best fifteen ships to use in the ARG schedule then this model can be used to determine that schedule. In addition the results are expected to show the three LSDs that contribute least to lift capacity of the ARG schedule. For purposes of comparison a typical schedule was used.

TYPICAL ARG SCHEDULE			
	Base Troops	NET Vehicles	NET Cargo
Nassau	1903	27189	133396
Nashville	659	13105	30809
Pensacola	303	9839	2940
	2865	50133	167144
Kearsarge	1894	21546	106820
Ponce	728	12567	31334
Carter Hall	405	20812	51722
	3027	54924	189876
Bataan	1737	21297	93423
Shreveport	665	12956	30365
Oak Hill	405	18280	43660
	2807	52533	167448
Wasp	1894	19763	92767
Trenton	721	13930	36195
Portland	276	13683	1394
	2891	47377	130356
Saipan	1904	27189	124627
Austin	727	11884	34334
Tortuga	393	17301	4305
	3024	56373	163266
ARG AVG	2923	52268	163618
STD DEV	99	3621	21349
MINIMUM	2807	47377	130356

PROPOSED ARG SCHEDULE			
	Base Troops	NET Vehicles	NET Cargo
Nassau	1903	27189	133396
Nashville	659	13105	30809
Tortuga	393	17301	4305
	2955	57595	168510
Kearsarge	1894	21546	106820
Trenton	721	13930	36195
Gunston Ha	404	17301	4305
	3019	52777	147320
Bataan	1737	21297	93423
Ponce	728	12567	31334
Oak Hill	405	18280	43660
	2870	52144	168417
Wasp	1894	19763	92767
Shreveport	665	12956	30365
Carter Hall	405	20812	51722
	2964	53531	174854
Saipan	1904	27189	124627
Austin	727	11884	34334
Ashland	408	17301	4305
	3039	56373	163266
ARG AVG	2969	54484	164473
STD DEV	62	2455	12020
MINIMUM	2870	52144	147320
WORST-CASE IMPROVEMEN	2.24%	10.06%	13.01%
OVERALL IMPROVEMENT	8.44%		

LSDs NOT USED			
Whidbey Isl	399	16945	4305
Ashland	408	17301	4305
Gunston Ha	404	17301	4305

LSDs NOT USED			
Whidbey Isl	399	16945	4305
Portland	276	13683	1394
Pensacola	303	9839	2940

Base troop capacity and net cargo capacity both reached their highest possible value and dominated net vehicle capacity. Net vehicle capacity almost reached its highest possible value of 52,682. In this case all three lift capacities showed improvement. Improvements of thirteen- percent for net cargo capacity, over ten-percent for net cargo capacity, and over eight-percent for overall improvement are all quite considerable.

These results show that when all LSDs are used in a rotation cycle there is a significant amount of lift capacity that is sacrificed in some ARGs. The Portland and the Pensacola clearly contribute least to lift capacity. The Pensacola is scheduled for decommissioning in the fourth quarter of fiscal year 1999, so little argument is necessary to remove the Pensacola from the ARG schedule. If the Portland (or the Pensacola) must be left in the rotation, it should not be scheduled to deploy with the Wasp or Bataan ARGs. It is preferred that the Portland be scheduled with the Saipan or Nassau ARGs. Since the Whidbey Island, Ashland, Gunston Hall, and the Tortuga have similar lift capacities any one of these ships could be substituted for another. The Whidbey Island can be used to replace these other three other ships in the schedule with little change to the worst-case lift capacity.

VII. RESULTS AND CONCLUSIONS

A. BROKEN STOWAGE FACTORS

Vehicle and cargo broken stowage factors for all ship classes can most accurately be estimated by the following averages.

Average Vehicle Broken Stowage Factor	Average Cargo Broken Stowage Factor
0.70	0.64

The results of this thesis are in agreement with the 1990 DoN Lift Study for Vehicle broken stowage factor. Cargo broken stowage factor, however, is a significant decrease from the 1990 DoN Lift Study. A large portion (80-90%) of cargo spaces onboard amphibious ships is for ammunition. The compatibility restrictions of ammunition may explain the lower result for the cargo broken stowage factor. After these results were achieved, it was discovered that the same result of 0.64 was observed during Desert Storm for ammunition on breakbulk/container type ships (not exactly the same, but similar to amphibious ships) according to the Military Traffic Management Command in their Logistics Handbook for Strategic Mobility Planning. (MTMCTEA REFERENCE 97-700-2)

B. LANDING CRAFT

The following Notional Landing Craft Load-out Table lists the expected landing craft embarked on each class of ship for a six-month deployment.

Six-Month Deployment Notional Landing Craft Load-out		
	LCAC	LCU
LHD	3	
LHA		4
LPH		
LPD-4		1
LSD-36	3	
LSD-36M	2	
LSD-41	4	
LSD-49	2	
LST		

The expected preboat load-outs for LCACs and LCUs average 985 and 1490 square feet respectively.

C. NET LIFT CAPACITIES OF SHIPS AND CLASS AVERAGES TABLE

The net capacity for each ship is determined by applying the above planning factors to gross lift values provided in the Gross Capacities of Ships and Class Averages Table in Appendix B. Troop bunks are the same value for gross and net. Net cargo capacity (cubic footage) is determined by multiplying the gross cargo capacity by the cargo broken stowage factor.

Net vehicle capacity (square footage) is determined by multiplying the gross vehicle capacity by the vehicle broken stowage factor and then adding preboat load-out. Preboat load-out is determined by multiplying the notional landing craft load-out value by the expected preboat load-out for the appropriate landing craft.

$$\text{Net Vehicle} = \begin{pmatrix} \text{Gross} \\ \text{Vehicle} \end{pmatrix} \times \begin{pmatrix} \text{Vehicle Broken} \\ \text{Stowage Factor} \end{pmatrix} + \begin{pmatrix} \text{Notional Landing} \\ \text{Craft Load-out} \end{pmatrix} \times \begin{pmatrix} \text{Expected Preboat} \\ \text{Load-out} \end{pmatrix}$$

The following example shows the net vehicle capacity determined for the Ponce (LPD-15).

$$12{,}332 = (15{,}824 \times 0.70) + (1 \times 1{,}255)$$

The resulting Net Capacities of Ships and Class Averages Table is provided in Appendix E.

D. DETERMINING AMPHIBIOUS READY GROUPS (ARGs)

With respect to the linear programming model discussed in Chapter VI, two conclusions can be drawn. First, the model itself would be of greater value when circumstances dictate that an ARG's lift capacity is given priority over other scheduling considerations. Second, the ARG lift capacity in the Atlantic Fleet can be significantly improved by simply removing the Pensacola and the Portland from the ARG schedule.

E. OBSERVATIONS AND RECOMMENDATIONS

Each ship should be able to maintain accurate capacity figures in its SLCP. In each SLCP, capacities in the Troop Cargo Capacities (section I) and the Troop Cargo Space Capability Breakdown (section VIII) should be in agreement. It is recommended that the validated capacities maintained by the CCOs at CNSL or CNSP be referred to when updating SLCPs. While it is recognized that every ship is different, it is nonetheless recommended that the Detailed Gross Capacities Table in Appendix C be utilized to provide consistency in compartments, cargo types, and capacities reported within ships in a class.

Review of Appendix C will show some disparities between SLCP totals and CNS(P/L) data. Given only these references and an inability to remeasure amphibious ship capacities, the correct capacity was determined to the best of the author's ability. It may be advisable to reexamine the SLCPs and capacities when a disparity exists.

Correctly interpreting EPMRs became the most difficult part of this thesis. The results of this thesis are dependent on the accuracy of these EPMRs. Presently the lift summary of the EPMR provides square footage and cubic footage of the different cargo categories of an entire ship. When a cargo category was reported in both square footage and cubic footage, it sometimes could not be determined if cargo was reported using both measurements or if two different groups of cargo were being reported. It was apparent that different CCOs were using different methods. It may be helpful to divide the lift summary into two sections, cargo stowage areas and vehicle stowage areas. It may also be helpful for the Pacific Fleet to adopt the Atlantic Fleet method of reporting square footage and cubic footage in the Organizational Recap section of the EPMR.

APPENDIX A. GLOSSARY OF TERMS AND ACRONYMS

ARG - Amphibious Ready Group

BSF - Broken Stowage Factor is applied to the available space for embarkation due to the loss between boxes, between vehicles, around stanchions, and over cargo. (Joint Pub 3-02.2)

Big Deck - refers to an LPH, LHA, or LHD.

CCO - Combat Cargo Officer is an embarkation officer assigned to major amphibious ships or naval staffs, functioning primarily as an adviser to and representative of the naval commander in matters pertaining to embarkation and debarkation of troops and their supplies and equipment. (Joint Pub 1-02)

CNSL - Commander, Naval Surface Forces U.S. Atlantic Fleet (COMNAVSURFLANT)

CNSP - Commander, Naval Surface Forces U.S. Pacific Fleet (COMNAVSURFPAC)

Combat Loading - The arrangement of personnel and the storage of equipment and supplies in a manner designed to conform to the anticipated tactical operation of the organization embarked. Each individual item is stowed so that it can be unloaded at the required time. (Joint Pub 1-02)

CPG - Commander Amphibious Group (COMPHIBGRU), the commander of a PHIBGRU will normally have amphibious squadrons (PHIBRONs) administratively assigned to it. In addition the PHIBGRU is capable of simultaneous tactical control of assigned units in executing all phases of an amphibious operation, up to and including a Marine Expeditionary Force-size or equivalent organization if required. (Joint Pub 3-02.2)

Detailed Load Plans - All of the individually prepared documents which, taken together, present in detail all instructions for the arrangement of personnel, and the loading of equipment for one or more units or other special grouping of personnel or material moving by highway, water, rail or air transportation. (Joint Pub 1-02)

DFM - Diesel Fuel Marine

DoN - Department of the Navy

EPMR - Embarked Personnel Material Report gives a consolidated, concise and up-to-date report of embarked personnel, equipment, and cargo. It is sent by message from each amphibious ship upon departure for a deployment or exercise.

JP-5 - Aviation Fuel

GAMS - The General Algebraic Modeling System is a high-level modeling system for mathematical programming problems. It consists of a language compiler and a stable of integrated high-performance solvers. GAMS is tailored for complex, large scale modeling applications, and allows you to build large maintainable models that can be adapted quickly to new situations.

Landing Craft - A craft employed in amphibious operations, specifically designed for carrying troops and equipment and for beaching, unloading, and retracting. Also used for logistic cargo resupply operations. Also used for logistic cargo resupply operations. (Joint Pub 1-02)

LCAC - Landing Craft Air Cushion is designed to land heavy vehicles, equipment, personnel, and cargo in an amphibious assault with the high speeds of a helicopterborne craft.

LCC - Amphibious Command Ship is a naval ship designed to serve as a floating command center, providing control facilities for embarked sea, air, and land commanders and their staffs.

LCM-8 - Landing Craft Mechanized designed to land heavy vehicles, equipment, personnel, and cargo in an amphibious assault.

LCU - Landing Craft Utility designed to land heavy vehicles, equipment, personnel, and cargo in an amphibious assault.

LFORM - Landing Forces Operational Reserve Material

LPD - Amphibious Transport Dock is a naval ship designed to transport and launch loaded amphibious craft and vehicles with their crews and embarked personnel in amphibious assault, and to render limited docking and repair service to small ships and craft; and one that is capable of acting as a control ship in an amphibious assault

LPH - Amphibious Assault Ship (helicopter) is a naval ship designed to transport and land troops and their essential helicopter transportable equipment and supplies by means of embarked helicopters during and amphibious assault.

LHA - Amphibious Assault Ship (general purpose) is a naval ship designed to embark, deploy, and land elements of a Marine landing force in an amphibious assault by helicopters, landing craft, amphibious vehicles, or a combination of these methods. (Joint Pub 1-02)

LHD - Amphibious Assault Ship (multipurpose) is a naval ship designed to embark, deploy, and land elements of a Marine landing force in an amphibious assault by helicopters, landing craft, amphibious vehicles, or a combination of these methods.

LSD - Dock Loading Ship is a naval ship designed to transport and launch loaded amphibious craft and vehicles with their crews and embarked personnel in amphibious assault, and to render limited docking and repair service to small ships and craft; and one that is capable of acting as a control ship in an amphibious assault. (Joint Pub 1-02)

LST - Tank Landing Ship is a naval ship designed to run up to the beach, lower their extended bow ramp, and offload tanks, artillery, and logistic vehicles.

MAGTF - Marine Air-Ground Task Force is a task organization of Marine forces (division, aircraft wing and service support groups) under a single command and structured to accomplish a specific mission. The Marine Air-Ground Task Force components will normally include command, aviation combat, ground combat, and combat service support elements (including Navy Support Elements) (Joint Pub 1-02)

MOGAS - Motor Gasoline

OPNAV - Office of the Chief of Naval Operations

Outsized Cargo - cargo that is larger than the generally accepted "standard pallet," and may be either mounted on a pallet or skids. It also includes large items that are not classified as vehicles, but must be considered separately due to handling/stowage requirements.

POL - Petroleum, Oils, and Lubricants

Preboat - The load-out or vehicle and cargo carrying capacity of landing craft carried in amphibious ships.

Primary Control Ship - In amphibious operations, a ship of the task force designated to control the movement of landing craft, amphibious vehicles, and landing ships to and from a beach.

Regular Cargo – this thesis uses this term to refer to all cargo that is not classified as Outsized cargo.

SLCP - Ship's Loading Characteristic Pamphlet

Undesignated Cargo – this thesis uses this term to refer to cargo where the location of stowage cannot be determined for certain. It could be stowed in either vehicle or cargo stowage areas.

APPENDIX B. GROSS CAPACITIES OF SHIPS AND CLASS AVERAGES TABLE

Ship		Troop Bunks			Gross Vehicle (sqft)	Gross Cargo (cuft)	Bulk POL (GAL)			SLCP Approval Date
		Base	Surge	Total			MOGAS	DFM	JP5	
LHD1	Wasp	1894	211	2105	24012	144948	0	1882249	484310	910201
LHD2	Essex	1631	182	1813	25212	144948	0	1882249	484310	970730
LHD3	Kearsarge	1894	213	2107	26558	166906	0	1897777	439685	960101
LHD4	Boxer	1688	184	1872	25212	144948	0	1882249	484310	961016
LHD5	Bataan	1737	184	1921	26203	145973	0	1854710	604915	971201
AVG		1769	195	1964	25439	149545	0	1879847	499506	
LHA1	Tarawa	1895	0	1895	24891	158827	8000	N/A	415940	970701
LHA2	Saipan	1904	0	1904	30327	194729	10865	N/A	417000	971201
LHA3	Belleau Wood	1904	0	1904	23120	116111	8000	N/A	415940	960601
LHA4	Nassau	1903	0	1903	30327	208431	10847	N/A	417009	961001
LHA5	Peleliu	1903	0	1903	25323	158827	8000	N/A	400000	980201
AVG		1902	0	1902	26798	167385	9142	0	413178	
LPH2	Guam	1542	206	1748	4036	47315	0	834000	290000	960207
AVG		1542	206	1748	4036	47315	0	834000	290000	
LPD4	Austin	727	188	915	14848	53647	21375	725975	205943	971201
LPD5	Ogden	724	202	926	14386	51174	23510	763199	236390	961112
LPD6	Duluth	698	221	919	16174	58869	18000	736199	216791	980201
LPD7	Cleveland	659	179	838	14102	46596	22114	?	282265	980201
LPD8	Dubuque	674	184	858	13857	56823	22069	763199	278913	960401
LPD9	Denver	673	178	851	16740	56854	20000	780337	283000	951209
LPD10	Juneau	682	178	860	13876	48783	23114	712531	303055	?
LPD12	Shreveport	665	176	841	16380	47445	23000	828366	332000	970301
LPD13	Nashville	659	208	867	16593	48139	22114	828337	333529	970601
LPD14	Trenton	721	198	919	17772	56555	17600	860919	350000	950811
LPD15	Ponce	728	192	920	15824	48960	23114	?	350625	931201
AVG		692	191	883	15505	52168	21455	777674	288410	
LSD49	Harpers Ferry	405	101	506	17105	78728	0	797764	50000	960816
LSD50	Carter Hall	405	101	506	26917	80816	0	755658	53230	961001
LSD51	Oak Hill	405	101	506	23300	68219	0	795701	53230	970915
AVG		405	101	506	22441	75921	0	783041	52153	
LSD41	Whidbey Island	399	100	499	18578	6727	0	797764	53000	970515
LSD42	Germantown	403	101	504	19087	6727	0	797764	53000	960301
LSD43	Fort McHenry	413	100	513	19087	6727	0	797764	53000	960301
LSD44	Gunston Hall	404	101	505	19087	6727	0	796164	50569	971201
LSD45	Comstock	402	102	504	19067	6727	0	838079	53000	970701
LSD46	Tortuga	393	102	495	19087	6727	0	797764	53000	940322
LSD47	Rushmore	403	101	504	19067	6727	0	?	53000	?
LSD48	Ashland	408	101	509	19087	6727	0	838081	53230	970311
AVG		403	101	504	19018	6727	0	943897	52725	
LSD36	Anchorage	334	0	334	17712	2753	0	N/A	31396	?
LSD39	Mount Vernon	299	58	357	16572	2036	0	N/A	31396	?
LSD40	Fort Fisher	248	72	320	17712	2044	0	N/A	31396	?
AVG	LSD36M Class	294	43	337	17332	2278	0	N/A	31396	
LSD37	Portland	276	64	340	16733	2178	0	949232	31386	960531
LSD38	Pensacola	303	20	323	11242	4593	0	920676	31387	970915
AVG	LSD36 Class	290	42	332	13988	3386	0	934954	31387	
LST 1184	Frederick	314	72	386	17501	4356	7197	229000	19055	?
LST 1194	La Moure County	315	68	383	16609	4339	7197	310000	19000	971201
AVG		315	70	385	17055	4348	7197	269500	19027.5	
TOTALS		34,034	4,749	38,783	769,323	2,509,686	296,116	30,152,951	8,830,601	
TOTALS w/o Guam & Ft Fisher		32,244	4,471	36,715	747,575	2,460,327	296,116	29,318,951	8,540,601	
LCC19	Blue Ridge	224	0	224	N/A	15056	0	N/A	?	?
LCC20	Mount Whitney	209	0	209	2336	17539	0	N/A	120399	971201
AVG		217	0	217	2336	16298	0	N/A	120399	

APPENDIX C. DETAILED GROSS CAPACITIES TABLE

LHD

Vehicle Square Feet

Compartment	Wasp	Essex	Kearsarge	Boxer	Bataan	
3rd Deck	14974	16174	14974	14974	N/A	
1st Platform	9038	9038	9038	9038	N/A	
SLCP Total	24012	25212	24012	24012	0	
Gross, used in Appendix B	24012	25212	26558	25212	26203	This Line Considered to be Actual
CNS(P/L)	24012	25212	26558	25212	N/A	
1990 DoN Lift	25500	N/A	N/A	N/A	N/A	

Cargo Cubic Feet

Cargo Type	Wasp	Essex	Kearsarge	Boxer	Bataan	
Ammunition	119860	119860	139697	119860	N/A	
Pyrotechnics	2909	2909	3317	2909	N/A	
Jettisonable Lockers	21	21	25	21	N/A	
POL (Packaged)	22158	22158	23867	22158	N/A	
SLCP Total	144948	144948	166906	144948	0	
Gross, used in Appendix B	144948	144948	166906	144948	158827	This Line Considered to be Actual
CNS(P/L)	144948	144948	166906	144948	N/A	
1990 DoN Lift	166600	N/A	N/A	N/A	N/A	

LHA

Vehicle Square Feet

Compartment	Tarawa	Saipan	Belleau W	Nassau	Peleliu	
3rd Deck	16161	21197	17941	21197	16161	
1st Platform		9130	5179	9130		
4th Deck	8730				9162	
SLCP Total	24891	30327	23120	30327	25323	
Gross, used in Appendix B	24891	30327	23120	30327	25323	This Line Considered to be Actual
CNS(P/L)	24891	36163	23120	36163	24891	
1990 DoN Lift	28700	28700	28700	28700	28700	

Cargo Cubic Feet

Cargo Type	Tarawa	Saipan	Belleau W	Nassau	Peleliu	
General	18330	62252	23859	55442	23849	
Ammunition	118709	121900	83324	141755	128580	
Pyrotechnics	2700		2160		2700	
Fuel Air Explosives	5374					
White Phosphorus	4762					
Demo		21				
Jettison Lockers		71				
POL (Packaged)	9759	10485	6768	11234	9217	
SLCP Total	159634	194729	116111	208431	164346	
Gross, used in Appendix B	158827	194729	116111	208431	158827	This Line Considered to be Actual
CNS(P/L)	158827	208237	116111	208431	158827	
1990 DoN Lift	128200	146200	137400	146600	147700	

The First Platform (Aft) on the Saipan and Nassau is a dual purpose space. The after portion is equipped with cargo tie-down tracks for stowage of outsized or heavy lift cargo. The SLCP totals assume this space is used for cargo, while the CNSL numbers have counted this area twice for both vehicle square feet and cargo cubic feet.

LPD-4

Vehicle Square Feet

Compartment	Austin	Ogden	Duluth	Cleveland	Dubuque	Denver	Juneau	Shreveport	Nashville	Trenton	Ponce
Upper Vehicle	6960	7128	7625	6727	5911	7110	6549	7343	7556	8736	7452
Lower Vehicle	7888	7258	8549	7375	7946	9630	7327	9037	9037	9036	8372
SLCP Total	14848	14386	16174	14102	13857	16740	13876	16380	16593	17772	15824
Gross, used in Appendix B	14848	14386	16174	14102	13857	16740	13876	16380	16593	17772	15824
CNS(P/L)	14848	14083	14083	14102	13858	12329	13876	16380	16593	17772	15824
DoN Lift	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000

Cargo Cubic Feet

Cargo Type	Austin	Ogden	Duluth	Cleveland	Dubuque	Denver	Juneau	Shreveport	Nashville	Trenton	Ponce
Ammunition	47129	44672	50780	41061	55368	50276	42100	41394	42319	43148	42977
Pyrotechnics	1502	1280	933	753	975	989	994	842	842	1088	968
Demo		531	457	337	456	460	492	357	357	492	421
Jettison Lockers	354	40	360	371	24	384	480	42	50	0	64
Special Weapons	4662	4651	6339	4074		4745	4717	4810	4571	4312	4459
POL (Packaged)										7515	
SLCP Total	53647	51174	58869	46596	56823	56854	48783	47445	48139	56555	48889
Gross, used in Appendix B	53647	51174	58869	46596	56823	56854	48783	47445	48139	56555	48960
CNS(P/L)	53647	51174	51188	51188	56553	56845	48783	47445	48139	56555	48960
1990 DoN Lift	55900	46200	55500	48200	51000	49700	50100	56000	50900	49800	48800

LSD-49

Vehicle Square Feet

Compartment	Harpers Fe	Carter Hall	Oak Hill	
Flight Deck	5830	7925	7808	
Truck Tunnel		1184	1184	
Boat Deck	3738	3245	3615	
Vehicle Turning Area	713	2227	1565	
Vehicle Stowage Area	6824	12336	9128	
SLCP Total	17105	26917	23300	
Gross, used in Appendix B	17105	26917	23300	This Line considered to be Actual
CNS(P/L)	14127	26917	23505	
1990 DoN Lift	20200	N/A	N/A	

Cargo Cubic Feet

Cargo Type	Harpers Fe	Carter Hall	Oak Hill	
General Cargo	13158	18966	12070	
Ammunition	61868	57846	51427	
Pyrotechnics		316	88	
Demo		18	16	
Jettison Lockers		4	1	
Lithium Batteries		82	64	
POL (Packaged)	3702	3584	2901	
SLCP Total	78728	80816	66567	
Gross, used in Appendix B	78728	80816	68219	This Line considered to be Actual
CNS(P/L)	50777	80816	68219	
1990 DoN Lift	67600	N/A	N/A	

LSD-41

Vehicle Square Feet

Compartment	Whidbey Is	Germantov	Fort McHe	Gunston H	Comstock	Tortuga	Rushmore	Ashland	
Flight Deck	7935	8444	8444	8444	8440	8444	N/A	8444	
Stbd Deck/Tunnel	2389	2389	2389	2389	2389	2389	N/A	2389	
Turntable	1018	1018	1018	1018	1002	1018	N/A	2016	
Well Deck w/4 LCACs	7236	7236	7236	7236	7236	7236	N/A	7236	
SLCP Total	18578	19087	19087	19087	19067	19087	0	20085	
Gross, used in Appendix B	18578	19087	19087	19087	19067	19087	19067	19087	This Line considered Actual
CNS(P/L)	18431	19067	19067	18431	19067	18431	19067	18431	
1990 DoN Lift	14600	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Cargo Cubic Feet

Cargo Type	Whidbey Is	Germantov	Fort McHe	Gunston H	Comstock	Tortuga	Rushmore	Ashland	
Ammunition	3924	3924	3924	3924	3924	3924	N/A	3924	
Pyrotechnics	396	396	396	396	396	396	N/A	396	
Demo	598	598	598	598	598	598	N/A	598	
Thermite Grenade Lkr	16						N/A		
Lithium Batteries	84						N/A		
Jettison Lockers			4	84	4	84	N/A	84	
POL (Packaged)	1725	1725	1725	1725	1725	1725	N/A	1725	
SLCP Total	6743	6643	6647	6727	6647	6727	0	6727	
Gross, used in Appendix B	6727	6727	6727	6727	6727	6727	6727	6727	This Line considered Actual
CNS(P/L)	6691	6727	6727	6727	6727	6727	6727	6727	
1990 DoN Lift	6807	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

Subtracting Whidbey Island, Thermite Grenade Lkr from Total achieves 6727
Well Deck data is with 4 LCAC's different than 90 DoN Lift notional lift

LSD-36M

Vehicle Square Feet

Compartment	Anchorage	Mount Ver	Fort Fisher
Super Deck	N/A	N/A	3865
Flight Deck	N/A	N/A	4661
Mezzanine Deck	N/A	N/A	7052
SLCP Total	0	0	15578
Gross, used in Appendix B	17712	16572	17712
CNS(P/L)	17712	16572	17712
1990 DoN Lift	8800	8800	8800

LSD-36

Vehicle Square Feet

Portland	Pensacola	
3653	3045	
4680	4543	
8400	3654	
16733	11242	
16733	11242	This Line considered to be Actual
3653	7548	
8800	8700	

Cargo Cubic Feet (LSD-36M)

Cargo Type	Anchorage	Mount Ver	Fort Fisher
General Cargo	N/A	N/A	
Ammunition	N/A	N/A	1853
Pyrotechnics	N/A	N/A	
Demo	N/A	N/A	99
Jettison Lockers	N/A	N/A	92
Thermite Lockers	N/A	N/A	
SLCP Total	0	0	2044
Gross, used in Appendix B	2753	2036	2044
CNS(P/L)	2753	2036	2044
1990 DoN Lift	2612	1477	2207

Cargo Cubic Feet (LSD-36)

Portland	Pensacola	
1595	1512	
190	1512	
60	1512	
	52	
9	5	
1854	4593	
2178	4593	This Line considered to be Actual
2178	1584	
1913	1025	

APPENDIX D. BROKEN STOWAGE FACTOR CALCULATIONS

Assuming All Outsized Cargo is Loaded in Vehicle Stowage and All Remaining Cargo is Stowed in Cargo Areas

Ship	Hull No.		VEHICLE STOWAGE AREAS GROSS (Sqft)	VEHICLE LOADED	Veh - Preboat	Vehicle Brok Stow	CARGO STOWAGE GROSS (Cuft)	CARGO LOADED	Cargo Brok Stow	% Cargo in Vehicle	Cargo BS - Veh BS
Wasp *	LHD-1	A	24012	20654	17481	0.761	144948	63537	0.589	1.0	-0.173
Essex *	LHD-2	P	25212	17790	15500	0.615	144948	82505	0.569	1.0	-0.046
Kearsarge *	LHD-3	A	26558	19378	17088	0.742	166906	126260	0.756	1.0	0.014
Boxer	LHD-4	P	25212	17692	14736	0.584	144948	142612	0.984	1.0	0.399
CLASS AVG	**LHD**		25249	18879	16201	0.672	150438	103728.5	0.735		0.063
Saipan	LHA-2	A	30327	24109	18954	0.720	194729	92093	0.479	1.0	-0.241
Belleau Wood	LHA-3	P	23120	16631	13675	0.591	116111	83496	0.757	1.0	0.165
Nassau	LHA-4	A	30327	26348	23000	0.846	208431	86358	0.421	1.0	-0.426
Peleliu *	LHA-5	P	25323	19487	15386	0.608	158827	88708	0.559	1.0	-0.049
CLASS AVG	**LHA**		27274	21644	17754	0.697	169525	87663.75	0.526		-0.171
Guam (Oct 97) *	LPH-9	A	4036	2284	2284	0.665	47315	36568	0.795	1.0	0.130
Guam (Jan 96)	LPH-9	A	4036	1748	1748	0.433	47315	43617	0.922	1.0	0.489
Austin *	LPD-4	A	14848	12155	10501	0.707	53647	39257	0.732	1.0	0.025
Ogden *	LPD-5	P	14386	9540	8285	0.674	51174	33835	0.769	1.0	0.095
Cleveland	LPD-7	P	14102	7949	6694	0.475	46596	26591	0.571	1.0	0.096
Juneau	LPD-10	P	13876	13307	13307	0.959	48783	14504	0.297	1.0	-0.662
Shreveport (97) **	LPD-12	A	16380	12538	11017	0.673	47445	40942	0.863	1.0	0.190
Shreveport (Aug 95)	LPD-12	A	16593	8832	8156	0.492	47445	49435	1.077	1.0	0.586
Nashville	LPD-13	A	16593	12880	8512	0.513	48139	48806	1.102	1.0	0.589
Trenton (Jan 98)	LPD-14	A	17772	9624	8276	0.466	56555	72347	1.279	1.0	0.814
Trenton (Jan 96)	LPD-14	A	17772	8770	7401	0.485	56555	67427	1.192	1.0	0.708
Ponce	LPD-15	A	15824	11090	9586	0.614	48960	39184	0.807	1.0	0.193
CLASS AVG	**LPD-4**		15815	10669	9174	0.598	50530	43233	0.878		0.280
Fort Fisher	LSD-40	P	17712	21900	20405	1.184	2044	0	0.000	1.0	-1.184
Portland (Jan 98)	LSD-37	A	16733	7615	6189	0.556	2178	3741	2.046	1.0	1.491
Portland (Jan 96)	LSD-37	A	16733	13026	11446	0.684	2178	236	0.108	1.0	-0.576
Pensacola	LSD-38	A	11242	10524.4	7376	0.656	4593	1509	0.334	1.0	-0.322
CLASS AVG	**LSD-36**		14903	10388	8337	0.640	2983	1828.6667	0.644		0.004
Whidbey Island	LSD-41	A	18578	14894	11791	0.635	6727	12495	1.944	1.0	1.309
Comstock	LSD-45	P	19067	13861	10905	0.602	6727	1250	0.409	1.0	-0.194
Tortuga	LSD-46	A	19087	15021	11080	0.689	6727	11636	1.743	1.0	1.054
Ashland **	LSD-48	A	19087	18011	13814	0.724	6727	70	0.011	1.0	-0.713
CLASS AVG	**LSD-41**		18955	15447	11898	0.662	6727	6362.75	1.120		0.458
Harpers Ferry	LSD-49	P	17105	16148	14178	0.844	78728	18404	0.264	1.0	-0.580
Carter Hall **	LSD-50	A	26917	17372	15779	0.747	80816	23765	0.808	1.0	0.061
Oak Hill **	LSD-51	A	23300	16761	15346	0.933	68219	21813	0.341	1.0	-0.592
CLASS AVG	**LSD-49**		22441	16760	15101	0.833	75921	21327	0.392		-0.441
La Moure County	LST-1179	A	16609	9285	9285	0.559	4339	1682	0.388	1.0	-0.171
						379182			1374683		
						553349			2017733		
					Overall	0.685		Overall	0.681		
					MAX	1.184		MAX	2.046	MAX	1.491
					MIN	0.433		MIN	0.000	MIN	-1.184

Table D.1. Outsized Cargo In Vehicle Stowage Areas

A/P indicates the Atlantic/Pacific Fleet

GROSS: total capacity for storage prior to load-out, in square footage for vehicle stowage and cubic Footage for cargo stowage (from Appendix B)

VEHICLE LOADED: total vehicles and cargo in square footage stowed in vehicle stowage areas

Veh - Preboat: VEHICLE LOADED minus the preboat load-out

Vehicle Broken Stowage: (Veh - Preboat)/(Gross-Space Available)

CARGO LOADED: total cargo in cubic footage loaded in cargo stowage spaces

Cargo Broken Stowage: CARGO LOADED/(Gross-Space Available)

% Cargo in Vehicle: the percentage of outsized cargo considered to be loaded in vehicle stowage areas

Cargo BS - Veh BS: is the difference in the two broken stowage factors

Space Available: space remaining after load-out is complete reported in both square footage and cubic footage (not displayed on this table)

Note: These assumptions could not be correct since they yield broken stowage factors above 1.0.

Broken Stowage Factors with Preboat Loadout Subtracted

Assume that Vehicle Broken Stowage is 6.9 Percent Greater than Cargo Broken Stowage Factors

			VEHICLE STOWAGE AREAS									CARGO STOWAGE AREAS									
Ship	Hull No.		GROSS (Sqft)	VEHICLE LOADED	Vehicle Reported	Undesignated Cargo	Outsized Cargo	Space Available	Preboat Load-out	Veh - Preboat	Vehicle Brok Stow	GROSS (Cuft)	CARGO LOADED	Regular Cargo	Undesignated Cargo	Outsized Cargo	Space Available	Cargo Brok Stow	Landing Craft	% Cargo in Vehicle	Cargo BS - Veh BS
Wasp *	LHD-1	A	24012	20654	16660	0	3994	1050	3173	17481	0.761	144948	63537	63537	0	24600	37000	0.589	3 LCAC	1.000	-0.173
Essex *	LHD-2	P	25212	17790	13114	0	4676	0	2290	15500	0.615	144948	82505	82505	0	33667	0	0.569	3 LCAC	1.000	-0.046
Kearsarge *	LHD-3	A	26558	19378	17240	0	2138	3534	2290	17088	0.742	166906	126260	126260	0	15374	0	0.756	3 LCAC	1.000	0.014
Boxer	LHD-4	P	25212	23131	11671	20629	6021	0	2956	20175	0.800	144948	105999	0	142612	43351	0	0.731	3 LCAC	0.430	-0.069
CLASS AVG	LHD		25249	20238	14671	5157	4207	1146	2677	17560.95	0.729	150438	94575	68076	35653	29248	9250	0.670	3 LCAC		-0.059
Saipan	LHA-2	A	30327	21878	16307	0	7802	4007	5155	16723	0.635	194729	108835	92093	0	58538	2502	0.566	4 LCU	0.714	-0.069
Belleau Wood	LHA-3	P	23120	18795	11537	2873	5094	0	2955.69231	15839	0.685	116111	67913	62807	20689	36677	5807	0.616	3 LCU	0.911	-0.069
Nassau	LHA-4	A	30327	21417	17349	0	8999	3147	3348	18069	0.665	208431	122293	86358	0	65574	3147	0.596	4 LCU	0.452	-0.069
Peleliu *	LHA-5	P	25323	19487	11846	0	7641	0	4101	15386	0.608	158827	88708	88708	0	48146	0	0.559	2CU1CAC	1.000	-0.049
CLASS AVG	LHA		27274	20394	14260	718	7384	1789	3890	16504	0.648	169525	96937	82492	5172	52234	2864	0.582	4 LCU		-0.066
Guam (Oct 97) *	LPH-9	A	4036	2951	223	667	2061	600	0	2951	0.859	47315	32908	32908	3660	12920	1291	0.715	N/A	1.000	-0.144
Guam (Jan 96)	LPH-9	A	4036	3408	454	1913	1294	0	0	3408	0.844	47315	36674	35199	8418	10251	0	0.775	N/A	0.921	-0.069
Austin *	LPD-4	A	14848	12155	9278	0	2877	0	1654	10501	0.707	53647	39257	39257	0	20035	0	0.732	1 LCU	1.000	0.025
Ogden *	LPD-5	P	14386	11390	5919	1850	3621	2089	1255	10135	0.824	51174	27643	27643	6192	25216	7169	0.628	1 LCU	1.000	-0.196
Cleveland	LPD-7	P	14102	9357	3397	2464	4552	0	1255	8102	0.575	46596	23550	17205	9386	32774	0	0.505	1 LCU	0.850	-0.069
Juneau	LPD-10	P	13876	10598	10059	0	3248	0	0	10598	0.764	48783	33915	14504	0	23275	0	0.695	N/A	0.166	-0.069
Shreveport (97) **	LPD-12	A	16380	12806	9366	931	3172	0	1521	11285	0.689	47445	39384	34240	6702	25130	0	0.830	1 LCU	0.838	0.141
Shreveport (Aug 95)	LPD-12	A	16593	11862	5419	3165	3413	0	676	11186	0.674	47445	27767	26803	22632	24405	1560	0.605	1 LCU	0.980	-0.069
Nashville	LPD-13	A	16593	15783	10154	6665	2726	0	4368	11415	0.688	48139	27394	0	48806	19576	3847	0.618	14 AAV	0.599	-0.069
Trenton (Jan 98)	LPD-14	A	17772	14436	6504	7641	3120	0	1348	13088	0.736	56555	37721	17331	55016	22541	0	0.667	1 LCU	0.737	-0.069
Trenton (Jan 96)	LPD-14	A	17772	12796	6257	9364	2513	2498	1369	11427	0.748	56555	38433	0	67427	18093	0	0.680	1 LCU	0.551	-0.069
Ponce	LPD-15	A	15824	12172	8572	4611	2518	220	1504	10668	0.684	48960	29819	6466	32718	14460	420	0.614	1 LCU	0.505	-0.069
CLASS AVG	LPD-4		15815	12336	7493	3669	3176	481	1495	10841	0.707	50530	32488	18345	24888	22551	1300	0.660	1 LCU		-0.047
Fort Fisher	LSD-40	P	17712	21900	19800	0	2100	5461	1970	19930	1.627	2044	3269	0	0	15120	50	1.639	2 LCAC	1.000	0.013
Portland (Jan 98)	LSD-37	A	16733	9412	7103	2520	512	5600	1426	7986	0.717	2178	1186	0	3741	1230	350	0.649	1 LCU	0.762	-0.069
Portland (Jan 96)	LSD-37	A	16733	12736	11758	0	1268	0	1580	11156	0.667	2178	1302	236	0	4666	0	0.598	1 LCU	0.772	-0.069
Pensacola	LSD-38	A	11242	10383	9543	0	981.4	0	3148	7235	0.644	4593	2596	1509	0	7521	75	0.575	3 LCAC	0.856	-0.069
CLASS AVG	LSD-36		14903	10844	9468	840	920	1867	2051	8792	0.674	2983	1695	582	1247	4472	142	0.596	3 LCAC		-0.078
Whidbey Island	LSD-41	A	18578	17674	8902	3570	5992	0	3103	14571	0.784	6727	4596	0	12495	43142	300	0.715	10 AAV	0.917	-0.069
Comstock	LSD-45	P	19067	13811	10821	0	3040	960	2956	10855	0.600	6727	1624	1250	0	22828	3668	0.531	3 LCAC	0.984	-0.069
Tortuga	LSD-46	A	19087	15982	14327	1662	694	3000	3941	12041	0.748	6727	4534	0	11636	3600	50	0.679	4 LCAC	0.702	-0.069
Ashland **	LSD-48	A	19087	17731	17611	0	400	0	4197	13534	0.709	6727	4082	70	0	5731	165	0.622	4 LCAC	0.300	-0.087
CLASS AVG	LSD-41		18955	16300	12915	1308	2532	990	3549	12750	0.710	6727	3709	330	6033	18825	1046	0.653	4 LCAC		-0.057
Harpers Perry	LSD-49	P	17105	14165	14165	0	1983	312	1970	12195	0.726	78728	38234	18404	0	19830	9039	0.549	2 LCAC	0	-0.178
Carter Hall **	LSD-50	A	26917	16975	16596	0	776	5796	1593	15382	0.728	80816	24651	23765	0	1730	51405	0.838	1 LCU	0.488	0.110
Oak Hill **	LSD-51	A	23300	14409	12695	0	4066	6856	1415	12994	0.790	68219	39351	21813	0	30316	4202	0.615	1 LCU	0.4215	-0.175
CLASS AVG	LSD-49		22441	15183	14485	0	2275	4321	1659	13523	0.746	75921	34079	21327	0	17292	21549	0.627	2 LCAC		-0.120
La Moure County	LST-1179	A	16609	9234	4198	0	5087	0	0	9234	0.556	4339	2116	1682	0	42932	0	0.488	N/A	0.9899	-0.068

	Vehicle		Cargo
	378207		1284785
	541098		2015739
Overall(-Fort Fisher)	0.699	Overall(-Fort Fisher)	0.637
Average(-Fort Fisher)	0.709	Average(-Fort Fisher)	0.642
Average (7 ships with detailed EPMRs)	0.731	Average (7 ships with detailed EPMRs)	0.650
Average (4 ships with Detailed Load Plans)	0.729	Average (4 ships with Detailed Load Plans)	0.726
Average (11 ships with detailed EPMRs or Load Plans)	0.730	Average (11 ships with detailed EPMRs or Load Plans)	0.678

* detailed EPMRs for 7 ships

** Detailed Load Plans Provided for 4 Ships

Harpers Perry did not achieve a Vehicle Broken Stowage Factor of 6.8 Percent Greater than Cargo Broken Stowage Factor.
Fort Fisher is the only ship to exceed Broken Stowage Factors of 1.0 and therefore will be removed from the sample population.
This chart is a good starting point, but the assumption that Vehicle Broken Stowage Factor is 6.8 percent greater than Cargo Broken Stowage Factors is too restrictive.

Table D.2. 6.9 Percent Difference in Broken Stowage Factors

Explanation of Table 2 and Table 4 Headings

A/P indicates the Atlantic/Pacific Fleet

VEHICLE STOWAGE AREAS

GROSS: total capacity for storage prior to load-out in square footage for vehicle stowage areas (from Appendix B)

VEHICLE LOADED: total vehicles and cargo in square footage stowed in vehicle stowage areas {VEHICLE LOADED = Vehicle Reported + (Unknown Cargo + Outsized Cargo) * % Cargo in Vehicle}

Vehicle Reported: total vehicle loaded

Unknown Cargo: regular cargo that may be stowed in either cargo stowate or vehicle stowage areas in square footage

Outsized Cargo: in square footage

Space Available: space remaining after load-out is complete reported in square footage

Preboat Loadout: square footage stowed in landing craft

Veh - Preboat: VEHICLE LOADED minus the Preboat Load-out

Vehicle Broken Stowage: (Veh - Preboat)/(GROSS-Space Available)

CARGO STOWAGE AREAS

GROSS: total capacity for storage prior to load-out in cubic footage for cargo stowage areass (from Appendix B)

CARGO LOADED: total cargo in cubic footage loaded in cargo stowage spaces {CARGO LOADED = Vehicle Reported + (Unknown Cargo + Outsized Cargo) * (1 - % Cargo in Vehicle)}

Regular Cargo: all regular cargo that is stowed in cargo stowage areas

Unknown Cargo: regular cargo that may be stowed in either cargo stowage or vehicle stowage areas in cubic footage

Outsized Cargo: in cubic footage

Space Available: space remaining after load-out is complete reported in cubic footage

Cargo Broken Stowage: CARGO LOADED/(GROSS-Space Available)

Landing Craft: describes type and number of landing craft embarked

% Cargo in Vehicle: the percentage of Outsized Cargo and Regular Cargo 2 considered to be loaded in vehicle stowage areas

Cargo BS - Veh BS: is the difference in the two broken stowage factors

Reducing the Range of Possible Broken Stowage Factors and Percent Cargo in Vehicle Stowage by Assuming all Broken Stowage Factors are Greater than 0.55 and Less than 0.95 and Assuming the Difference between Cargo and Vehicle Broken Stowage Factors are Less than 0.25

Ship	Hull No.		Broken Stowage Factor Vehicle	Broken Stowage Factor Cargo	Low %Cargo Vehicle	Broken Stowage Factor Vehicle	Broken Stowage Factor Cargo	High %Cargo Vehicle	Size of Reduced Ranges Broken Stowage Factor Vehicle	Size of Reduced Ranges Broken Stowage Factor Cargo	Size of Reduced Ranges %Cargo Vehicle	MIN	AVG of 6.8 Percent Difference and Close to 0.73 Broken Stow 0.73 Vehicle	6.9 Percent	Average
Wasp *	LHD-1	A	0.587	0.816	0	0.761	0.589	1	0.174	0.228	1.000	0.174		1.000	1.000
Essex *	LHD-2	P	0.550	0.650	0.65	0.615	0.569	1	0.065	0.081	0.350	0.065		1.000	1.000
Kearsarge *	LHD-3	A	0.649	0.849	0	0.742	0.756	1	0.093	0.092	1.000	0.092		1.000	1.000
Boxer	LHD-4	P	0.656	0.906	0.2935	0.882	0.632	0.5072	0.226	0.274	0.214	0.214	0.364	0.430	0.397
CLASS AVG	LHD		0.611	0.805	0.236	0.750	0.637	0.877	0.139	0.169	0.641	0.139			
Saipan	LHA-2	A	0.550	0.654	0.425	0.651	0.550	0.768	0.102	0.104	0.343	0.102	0.768	0.714	0.741
Belleau Wood	LHA-3	P	0.558	0.808	0.542	0.716	0.569	1	0.158	0.238	0.458	0.158	1.000	0.911	0.956
Nassau	LHA-4	A	0.550	0.707	0.105	0.712	0.550	0.595	0.162	0.157	0.490	0.157	0.595	0.452	0.524
Peleliu *	LHA-5	P	0.550	0.616	0.81	0.608	0.559	1	0.057	0.058	0.190	0.057		1.000	1.000
CLASS AVG	LHA		0.552	0.696	0.471	0.672	0.557	0.841	0.120	0.139	0.370	0.120			
Guam (Oct 97) *	LPH-9	A	0.588	0.838	0.659	0.859	0.715	1	0.271	0.123	0.341	0.123		1.000	1.000
Guam (Jan 96)	LPH-9	A	0.631	0.881	0.6529	0.907	0.744	1	0.276	0.137	0.347	0.137	0.777	0.921	0.849
Austin *	LPD-4	A	0.630	0.880	0.603	0.707	0.732	1	0.077	0.148	0.397	0.077		1.000	1.000
Ogden *	LPD-5	P	0.653	0.903	0.615	0.824	0.628	1	0.171	0.275	0.385	0.171		1.000	1.000
Cleveland	LPD-7	P	0.550	0.550	0.8	0.550	0.550	0.8	0.000	0.000	0.000	0.000	0.800	0.850	0.825
Juneau	LPD-10	P	0.725	0.774	0	0.823	0.574	0.421	0.099	0.201	0.421	0.099	0.020	0.166	0.093
Shreveport (97) **	LPD-12	A	0.659	0.910	0.72	0.729	0.722	1	0.070	0.188	0.280	0.070		0.838	0.838
Shreveport (Aug 95)	LPD-12	A	0.585	0.835	0.755	0.682	0.584	1	0.097	0.251	0.245	0.097	1.000	0.980	0.990
Nashville	LPD-13	A	0.602	0.852	0.448	0.713	0.550	0.644	0.111	0.303	0.196	0.111	0.644	0.599	0.622
Trenton (Jan 98)	LPD-14	A	0.639	0.889	0.5755	0.788	0.550	0.8225	0.150	0.339	0.247	0.150	0.726	0.737	0.732
Trenton (Jan 96)	LPD-14	A	0.640	0.890	0.4116	0.810	0.559	0.63	0.170	0.330	0.218	0.170	0.527	0.551	0.539
Ponce	LPD-15	A	0.582	0.832	0.2815	0.714	0.550	0.571	0.132	0.281	0.290	0.132	0.571	0.505	0.538
CLASS AVG	LPD-4		0.626	0.831	0.521	0.734	0.600	0.789	0.108	0.232	0.268	0.108			
Portland (Jan 98)	LSD-37	A	0.688	0.938	0.655	0.727	0.550	0.7977	0.039	0.388	0.143	0.039	0.798	0.762	0.780
Portland (Jan 96)	LSD-37	A	0.656	0.906	0.6276	0.668	0.550	0.794	0.013	0.356	0.166	0.013	0.794	0.772	0.783
Pensacola	LSD-38	A	0.628	0.878	0.6735	0.645	0.550	0.87	0.017	0.327	0.197	0.017	0.870	0.856	0.863
CLASS AVG	LSD-36		0.657	0.907	0.652	0.680	0.550	0.821	0.023	0.357	0.169	0.023			
Whidbey Island	LSD-41	A	0.770	0.950	0.8903	0.794	0.550	0.9365	0.024	0.400	0.046	0.024	0.890	0.917	0.904
Comstock	LSD-45	P	0.592	0.843	0.9418	0.599	0.550	0.981	0.007	0.293	0.039	0.007	0.981	0.984	0.982
Tortuga	LSD-46	A	0.731	0.950	0.5838	0.757	0.550	0.759	0.026	0.400	0.175	0.026	0.584	0.702	0.643
Ashland **	LSD-48	A	0.703	0.884	0	0.711	0.561	0.37	0.008	0.323	0.370	0.008		0.300	0.300
CLASS AVG	LSD-41		0.699	0.907	0.604	0.715	0.553	0.762	0.016	0.354	0.158	0.016			
Harpers Ferry	LSD-49	P	0.726	0.549	0	0.726	0.549	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Carter Hall **	LSD-50	A	0.710	0.867	0	0.747	0.808	1	0.037	0.059	1.000	0.037		0.488	0.488
Oak Hill **	LSD-51	A	0.686	0.814	0	0.816	0.566	0.525	0.130	0.249	0.525	0.130		0.422	0.422
CLASS AVG	LSD-49		0.707	0.743	0.000	0.763	0.641	0.508	0.056	0.102	0.508	0.056			
La Moure County	LST-1179	A	0.550	0.684	0.97	0.554	0.550	0.984	0.004	0.135	0.014	0.004	0.984	0.990	0.987
											MIN	0.007	0.058	0.039	0.007

Table D.3. Reduced Ranges

Low % Cargo in Vehicle is the lowest possible value for % Cargo in Vehicle Stowage Areas and still meet the above assumptions, Broken Stowage Vehicle and Cargo are the accompanying Broken Stowage Factors

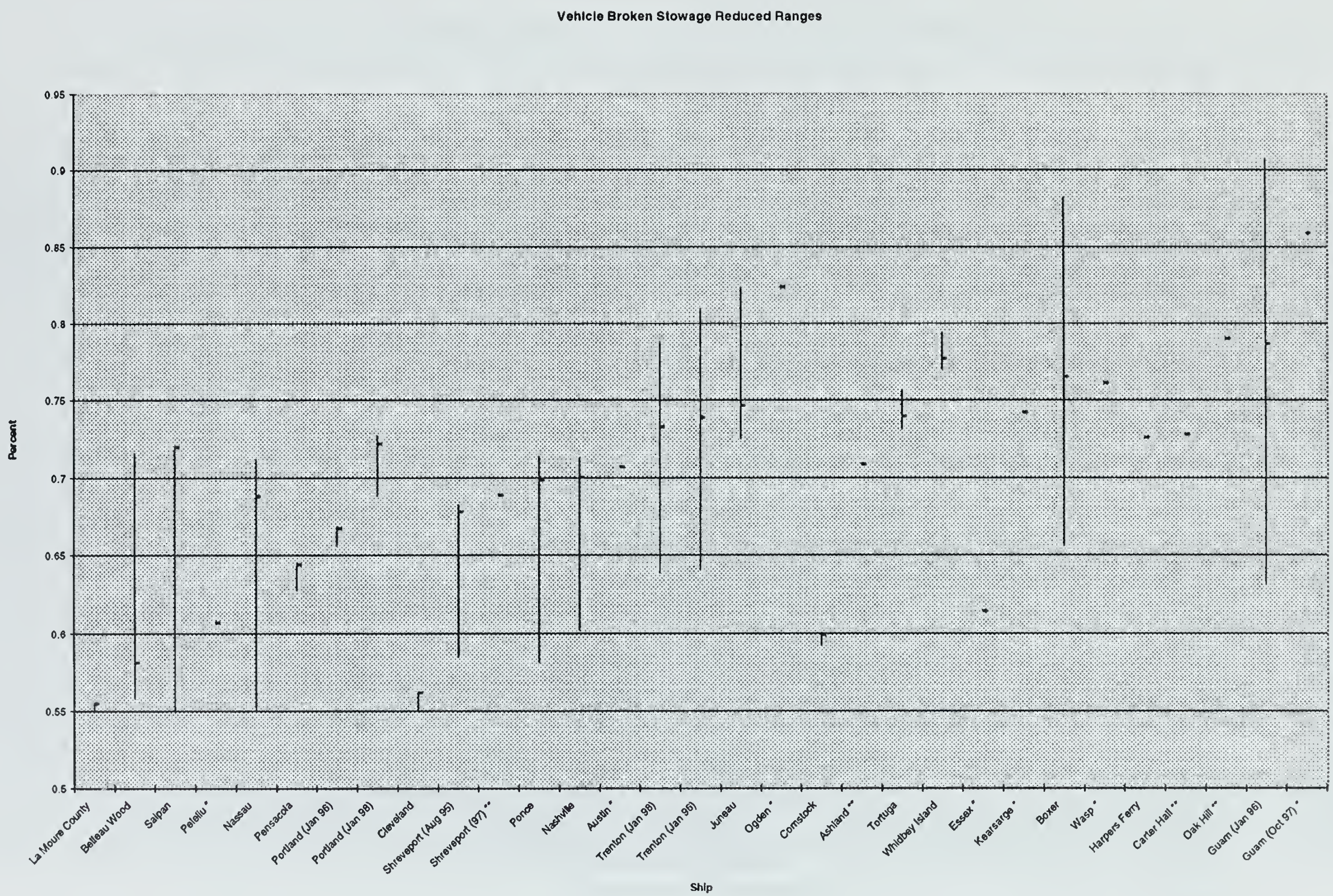
High % Cargo in Vehicle is the highest possible value for % Cargo in Vehicle Stowage Areas and still meet the above assumptions, Broken Stowage Vehicle and Cargo are the accompanying Broken Stowage Factors

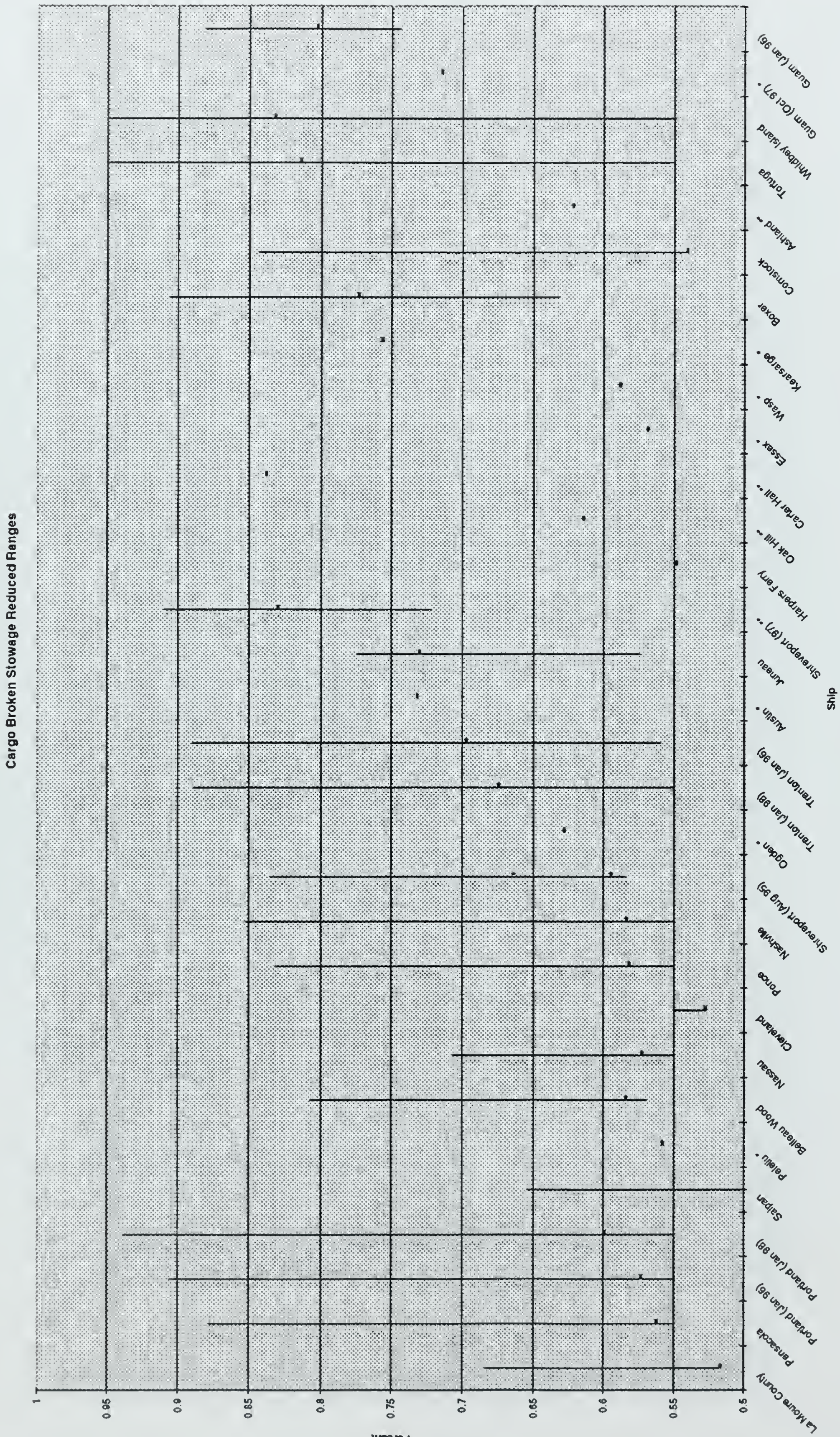
Size of Reduced Ranges is the size of the ranges of Vehicle and Cargo Broken Stowage Factors and the % Cargo in Vehicle after the above assumptions are met

Minimum is the smallest range of Vehicle and Cargo Broken Stowage Factors and % Cargo in Vehicle

The final column is the AVG of and the % Cargo in Vehicle when Vehicle Broken Stowage is 0.73 or as close to 0.73 and still meet the above assumptions(0.73 Vehicle) and the % Cargo in Vehicle Stowage Areas to achieve a 6.9 % difference in Broken Stowage Factors (6.9 Percent) , taken from the 6.9 Percent Table

The final column is the % Cargo in Vehicle Stowage used to determine final calculations in Table 4.


Vehicle Broken Stowage Reduced Ranges
Percent
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
La Moure County
Belleau Wood
Saipan
Peleliu *
Nassau
Pensacola
Portland (Jan 96)
Portland (Jan 98)
Cleveland
Shreveport (Aug 95)
Shreveport (97) **
Ponce
Nashville
Austin *
Trenton (Jan 98)
Trenton (Jan 96)
Juneau
Ogden *
Comstock
Ashland **
Tortuga
Whidbey Island
Essex *
Kearsarge *
Boxer
Wasp *
Harpers Ferry
Carter Hall **
Oak Hill **
Guam (Jan 96)
Guam (Oct 97) *
Ship


Cargo Broken Stowage Reduced Ranges
Percent
Ship
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Guam (Jan 96)
Guam (Oct 97) *
Whidbey Island
Tortuga
Ashland **
Comstock
Boxer
Kearsarge *
Wasp *
Essex *
Carter Hall **
Oak Hill **
Harpers Ferry
Shreveport (97) **
Juneau
Austin *
Trenton (Jan 96)
Trenton (Jan 98)
Ogden *
Shreveport (Aug 95)
Nashville
Ponce
Cleveland
Nassau
Belleau Wood
Peleliu *
Saipan
Portland (Jan 98)
Portland (Jan 96)
Pensacola
La Moure County

FINAL CALCULATIONS

Broken Stowage Factors with Preboat Loadout Subtracted

Considered To Be ACTUAL

			VEHICLE STOWAGE AREAS									CARGO STOWAGE AREAS									
Ship	Hull No.		GROSS (Sqft)	VEHICLE LOADED	Vehicle Reported	Undesignated Cargo	Outsized Cargo	Space Available	Preboat Load-out	Vehicle - Preboat	Vehicle Brok Stow	Gross (Cuft)	CARGO LOADED	Regular Cargo	Undesignated Cargo	Outsized Cargo	Space Available	Cargo Brok Stow	Landing Craft	% Cargo in Vehicl	Cargo BS - Veh BS
Wasp *	LHD-1	A	24012	20654	16660	0	3994	1050	3173	17481	0.761	144948	63537	63537	0	24600	37000	0.589	3 LCAC	1.000	-0.173
Essex *	LHD-2	P	25212	17790	13114	0	4676	0	2290	15500	0.615	144948	82505	82505	0	33667	0	0.569	3 LCAC	1.000	-0.046
Kearsarge *	LHD-3	A	26558	19378	17240	0	2138	3534	2290	17088	0.742	166906	126260	126260	0	15374	0	0.756	3 LCAC	1.000	0.014
Boxer	LHD-4	P	25212	22251	11671	20629	6021	0	2956	19295	0.765	144948	112136	0	142612	43351	0	0.774	3 LCAC	0.397	0.008
CLASS AVG	LHD		25249	20018	14671	5157	4207.25	1146	2677	17341	0.719	150438	96109	68076	35653	29248	9250	0.681	3 LCAC		-0.039
Saipan	LHA-2	A	30327	24109	16307	0	7802	4007	5155	18954	0.720	194729	92093	92093	0	58538	2502	0.479	4 LCU	1.000	-0.241
Belleau Wood	LHA-3	P	23120	16404	11537	2873	5094	0	2956	13449	0.582	116111	64439	62807	20689	36677	5807	0.584	3 LCU	0.956	0.003
Nassau	LHA-4	A	30327	22060	17349	0	8999	3147	3348	18712	0.688	208431	117604	86358	0	65574	3147	0.573	4 LCU	0.524	-0.116
Peleliu *	LHA-5	P	25323	19487	11846	0	7641	0	4101	15386	0.608	158827	88708	88708	0	48146	0	0.559	2CU1CAC	1.000	-0.049
CLASS AVG	LHA		27274	20515	14260	718	7384	1789	3890	16625	0.652	169524.5	90711.034	82492	5172	52234	2864	0.544	4 LCU		-0.108
Guam (Oct 97) *	LPH-9	A	4036	2951	223	667	2061	600	0	2951	0.859	47315	32908	32908	3660	12920	1291	0.715	N/A	1.000	-0.144
Guam (Jan 96)	LPH-9	A	4036	3177	454	1913	1294	0	0	3177	0.787	47315	38018	35199	8418	10251	0	0.804	N/A	0.849	0.016
Austin *	LPD-4	A	14848	12155	9278	0	2877	0	1654	10501	0.707	53647	39257	39257	0	20035	0	0.732	1 LCU	1.000	0.025
Ogden *	LPD-5	P	14386	11390	5919	1850	3621	2089	1255	10135	0.824	51174	27643	27643	6192	25216	7169	0.628	1 LCU	1.000	-0.196
Cleveland	LPD-7	P	14102	9183	3397	2464	4552	0	1255	7929	0.562	46596	24594	17205	9386	32774	0	0.528	1 LCU	0.825	-0.034
Juneau	LPD-10	P	13876	10361	10059	0	3248	0	0	10361	0.747	48783	35614	14504	0	23275	0	0.730	N/A	0.093	-0.017
Shreveport (97) **	LPD-12	A	16380	12806	9366	931	3172	0	1521	11285	0.689	47445	39384	34240	6702	25130	0	0.830	1 LCU	0.838	0.141
Shreveport (Aug 95)	LPD-12	A	16593	11930	5419	3165	3413	0	676	11254	0.678	47445	27285	26803	22632	24405	1560	0.595	1 LCU	0.990	-0.084
Nashville	LPD-13	A	16593	15992	10154	6665	2726	0	4368	11624	0.701	48139	25869	0	48806	19576	3847	0.584	14 AAV	0.622	-0.117
Trenton (Jan 98)	LPD-14	A	17772	14376	6504	7641	3120	0	1348	13028	0.733	56555	38151	17331	55016	22541	0	0.675	1 LCU	0.732	-0.058
Trenton (Jan 96)	LPD-14	A	17772	12656	6257	9364	2513	2498	1369	11287	0.739	56555	39442	0	67427	18093	0	0.697	1 LCU	0.539	-0.042
Ponce	LPD-15	A	15824	12407	8572	4611	2518	220	1504	10903	0.699	48960	28262	6466	32718	14460	420	0.582	1 LCU	0.538	-0.117
CLASS AVG	LPD-4		15815	12326	7493	3669	3176	481	1495	10831	0.706	50530	32550	18345	24888	22551	1300	0.661	1 LCU		-0.045
Portland (Jan 98)	LSD-37	A	16733	9467	7103	2520	512	5600	1426	8041	0.722	2178	1096	0	3741	1230	350	0.599	1 LCU	0.780	-0.123
Portland (Jan 96)	LSD-37	A	16733	12751	11758	0	1268	0	1580	11171	0.668	2178	1250	236	0	4666	0	0.574	1 LCU	0.783	-0.094
Pensacola	LSD-38	A	11242	10390	9543	0	981	0	3148	7242	0.644	4593	2541	1509	0	7521	75	0.562	3 LCAC	0.863	-0.082
CLASS AVG	LSD-36		14903	10869	9468	840	920	1867	2051	8818	0.676	2983	1629	582	1247	4472	141.6667	0.573	3 LCAC		-0.103
Whidbey Island	LSD-41	A	18578	17545	8902	3570	5992	0	3103	14442	0.777	6727	5349	0	12495	43142	300	0.832	10 AAV	0.904	0.055
Comstock	LSD-45	P	19067	13807	10821	0	3040	960	2956	10851	0.599	6727	1654	1250	0	22828	3668	0.541	3 LCAC	0.982	-0.059
Tortuga	LSD-46	A	19087	15842	14327	1662	694	3000	3941	11901	0.740	6727	5438	0	11636	3600	50	0.814	4 LCAC	0.643	0.075
Ashland **	LSD-48	A	19087	17731	17611	0	400	0	4197	13534	0.709	6727	4082	70	0	5731	165	0.622	4 LCAC	0.300	-0.087
CLASS AVG	LSD-41		18955	16231	12915	1308	2532	990	3549	12682	0.706	6727	4131	330	6033	18825	1046	0.727	4 LCAC		0.021
Harpers Ferry	LSD-49	P	17105	14165	14165	0	1983	312	1970	12195	0.726	78728	38234	18404	0	19830	9039	0.549	2 LCAC	0.000	-0.178
Carter Hall **	LSD-50	A	26917	16975	16596	0	776	5796	1593	15382	0.728	80816	24651	23765	0	1730	51405	0.838	1 LCU	0.488	0.110
Oak Hill **	LSD-51	A	23300	14409	12695	0	4066	6856	1415	12994	0.790	68219	39351	21813	0	30316	4202	0.615	1 LCU	0.422	-0.175
CLASS AVG	LSD-49		22441	15183	14485	0	2275	4321	1659	13523	0.746	75921	34079	21327	0	17292	21549	0.627	2 LCAC		-0.120
La Moure County	LST-1179	A	16609	9219	4198	0	5087	0	0	9219	0.555	4339	2242	1682	0	42932	0	0.517	N/A	0.987	-0.038
											377270							1269597			
											541098							2015739			

* detailed EPMRs for 7 ships

** Detailed Load Plans Provided for 4 Ships

	Vehicle	Cargo	Cargo BS - Veh BS
Overall	0.697	0.630	
Average	0.705	0.647	-0.059
Average (7 ships with detailed EPMRs)	0.731	0.628	-0.101
Average (4 ships with Detailed Load Plans)	0.729	0.726	-0.003
Average (11 ships with detailed EPMRs or Load Plans)	0.730	0.661	-0.069

	Vehicle	Ship	Cargo	Ship
HI	0.859	Guam (Oct 97) *	0.838	Carter Hall **
LOW	0.555	La Moure County	0.479	Saipan

Table D.6. Final Calculations

APPENDIX E. NET CAPACITIES OF SHIPS AND CLASS AVERAGES TABLE

Ship		Troop Bunks Base	Troop Bunks Surge	Troop Bunks Total	Net Vehicle (sqft)	Net Cargo (cuft)
LHD1	Wasp	1894	211	2105	19763	92767
LHD2	Essex	1631	182	1813	20603	92767
LHD3	Kearsarge	1894	213	2107	21546	106820
LHD4	Boxer	1688	184	1872	20603	92767
LHD5	Bataan	1737	184	1921	21297	93423
AVG		1769	195	1964	20763	95709
LHA1	Tarawa	1895	0	1895	23384	101649
LHA2	Saipan	1904	0	1904	27189	124627
LHA3	Belleau Wood	1904	0	1904	22144	74311
LHA4	Nassau	1903	0	1903	27189	133396
LHA5	Peleliu	1903	0	1903	23686	101649
AVG		1902	0	1902	24718	107126
LPD4	Austin	727	188	915	11884	34334
LPD5	Ogden	724	202	926	11560	32751
LPD6	Duluth	698	221	919	12812	37676
LPD7	Cleveland	659	179	838	11361	29821
LPD8	Dubuque	674	184	858	11190	36367
LPD9	Denver	673	178	851	13208	36387
LPD10	Juneau	682	178	860	11203	31221
LPD12	Shreveport	665	176	841	12956	30365
LPD13	Nashville	659	208	867	13105	30809
LPD14	Trenton	721	198	919	13930	36195
LPD15	Ponce	728	192	920	12567	31334
AVG		692	191	883	12343	33387
LSD49	Harpers Ferry	405	101	506	13944	50386
LSD50	Carter Hall	405	101	506	20812	51722
LSD51	Oak Hill	405	101	506	18280	43660
LSD52	Pearl Harbor	406	102	508	18770	43520
AVG		405	101	507	17951	47322
LSD41	Whidbey Island	399	100	499	16945	4305
LSD42	Germantown	403	101	504	17301	4305
LSD43	Fort McHenry	413	100	513	17301	4305
LSD44	Gunston Hall	404	101	505	17301	4305
LSD45	Comstock	402	102	504	17287	4305
LSD46	Tortuga	393	102	495	17301	4305
LSD47	Rushmore	403	101	504	17287	4305
LSD48	Ashland	408	101	509	17301	4305
AVG		403	101	504	17253	4305
LSD36	Anchorage	334	0	334	15353	1762
LSD39	Mount Vernon	299	58	357	14555	1303
AVG	LSD36M Class	317	29	346	14954	1532
LSD37	Portland	276	64	340	13683	1394
LSD38	Pensacola	303	20	323	9839	2940
AVG	LSD36 Class	290	42	332	11761	2167
LST 1184	Frederick	314	72	386	12251	2788
LST 1194	La Moure County	315	68	383	11626	2777
AVG		315	70	385	11939	2782
TOTALS		32,650	4,573	37,223	650,318	1,618,129

APPENDIX F. SAMPLE OF APPLICABLE SLCP PAGES

USS SHREVEPORT (LPD-12)

SECTION I

GENERAL

1. PRINCIPAL CHARACTERISTICS

Ship Type and Class ---------------------------- Amphibious Transport Dock LPD-4 (AUSTIN Class) Flag Configured

Length (Overall) ------------------------------- 569'

Beam --- 84'1"

Draft, Maximum (Full Load) --------------------- 21'6"

Draft Ballasted -------------------------------- 32'

Displacement Tonnage (Full Load) S/T ----------- 16,912

Freeboard to Main Deck ------------------------- 33' AFT, 41'11" FWD

Freeboard to Flight Deck ----------------------- 33'

2. ORGANIC LANDING CRAFT, BOATS AND HELICOPTERS

	LANDING CRAFT					HELO
TYPE	LCM-8	LCM-6	LCM-6 (HS)	UB	LCPL	
QTY	0	0	0	1	2	0

3. WELL DECK CAPACITY

LCM-6 Equivalents: 9

LCM-8 Equivalents: 4

LCU Equivalents: 1

LCAC Equivalents: 1

4. STAFF, TROOP AND CREW LIVING ACCOMMODATIONS SUMMARY

	FLAG OFFICER	OFFICER	SNCO/CPO (E7-E9)	SSGT/PO1 (E6)*	ENL	TOT
NAVAL STAFF	1	30	4	0	54	89
LANDING FORCE (NORMAL)	0	79	26	0	560	665
LANDING FORCE (SURGE)	0	0	0	0	176	176
TOTAL	1	109	30	0	790	930
CREW	0	30	29	0	463	522

*No designated E-6 berthing. E-6 berthing included with E1/E5.

5. MEDICAL CAPACITIES

Operating Rooms: 1

Intensive Care Beds: 0

USS SHREVEPORT (LPD-12)

Isolation Rooms/Beds: 1/4

Recovery Wards/Beds: 1/8

6. TROOP CARGO SPACE CAPACITIES

	SQUARE FEET	CUBIC FEET	FIGURES SHOWN ARE ACTUAL SQFT AND CUFT TOTALS. NO REDUCTION WAS MADE FOR LFORM, MLA, AVCAL, BOAT HAVEN, ETC., STOWAGE SPACE REQUIREMENTS, AND NO BROKEN STOWAGE FACTORS HAVE BEEN APPLIED.	
GENERAL CARGO	NOTE 1	NOTE 1		
AMMUNITION	6,437**	41,394		
PYROTECHNICS	151**	842		
DEMOLITIONS	64**	357		
JETTISONABLE LOCKERS	NOTE 2	42		
SPECIAL WEAPONS	740**	4810	55 GAL DRUM CAP	MAXIMUM USEABLE CAPACITY (GALS)
POL (PACKAGED)	***	***	***	
JP-5 (BULK) (AVIATION)	XXX	XXX	XXX	332,000
JP-5 (BULK) (GROUND)	XXX	XXX	XXX	NOTE 3
MOGAS (BULK)	XXX	XXX	XXX	23,000
DIESEL "DFM" (BULK)	XXX	XXX	XXX	NOTE 3 828,366
VEHICLES	16,380		VEHICLES SQFT FIGURE IS TOTAL SQUARE FOOTAGE AVAILABLE IN DESIGNATED VEHICLE STOWAGE AREAS AND DOES NOT INCLUDE WELL DECK, FLIGHT DECK, AND HANGAR DECK.	
FLIGHT DECK	13,809**	XXX		
HANGAR DECK	3,543**	XXX		
WELL DECK WITHOUT WATER BARRIER RAISED	8,036**	XXX		
WELL DECK (AFT) WITH WATER BARRIER RAISED	N/A	XXX		
TOTALS	16,380	47,445		

NOTE 1 - AMMUNITION HOLDS HAVE OPERATIONAL USE AS CARGO STOWAGE SPACES.

NOTE 2 - THERE ARE 6 JETTISONABLE LOCKERS ON THE CATWALK ADJACENT TO THE FLIGHT DECK FOR THE STORAGE OF LITHIUM BATTERIES. COORDINATE WITH THE CCO IF USE OF THESE IS CONTEMPLATED.

NOTE 3 - ALL JP-5 IS FILTERED TWICE AND THEREFORE CLASSIFIED AS AVIATION QUALITY FUEL. DFM IS DISPENSED TO LANDING FORCE UNITS AS REQUIRED TO SUPPORT MISSION OBJECTIVES. TOTAL DFM LISTED IS THE TOTAL SHIPS CAPACITY.

* - REFER TO SECTION VIII (TROOP CARGO SPACE CAPACITY BREAKDOWN) FOR DETAILED INFORMATION ON SPECIFIC SPACES.

** - NOT INCLUDED IN TOTALS.

*** - SHARED STOWAGE WITH VEHICLES.

SECTION VIII

TROOP CARGO SPACE CAPACITY BREAKDOWN

DECK/ PLATFORM LEVEL	HOLD NUMBER	VEHICLE SQUARE FEET	DESIGNATED CARGO SPACE - CUBIC FEET							PALLET SQUARES (40X48)
			GEN	AMMO	PYRO	DEMO	JETT LOCKER	SPECIAL WEAPONS	POL (PKG)	
FLIGHT DECK	1	13,809****								
PYROTECHNICS LOCKER	1		*		842					7
DEMOLITIONS MAGAZINE	1		*			357				3
UPPER VEHICLE	3	7,343	*							
LOWER VEHICLE	4	9,037 ***	*						*	564
WELL DECK	4	8,036****								
1ST PLATFORM FORWARD	5		*	11,908						114
1ST PLATFORM AFT	5		*	13,013						118
2ND PLATFORM FORWARD	6		*	5,861						54
2ND PLATFORM AFT	6		*	10,612						98
SPECIAL WEAPONS	6		*					4,810 **		40
JETTISONABLE LOCKERS	VAR						42			
TOTALS		16,380		41,394	842	357	42	4,810		998

TROOP CARGO SPACE CAPACITY BREAKDOWN

*	General Cargo may be stowed in LFORM Magazine's depending on space available. General Cargo stowed in these magazines must be compatible with the LFORM. General Cargo may also be stowed in Upper Vehicle Stowage in lieu of vehicles. It is also acceptable to stow a mixture of vehicles and cargo in lower vehicle stowage.
**	The special weapons magazine is designated for special situation. The ship's highly pilferrable LFORM items are stored in this area. Special permission must be granted from the Commanding Officer of the ship to use this space.
***	Available space used for cargo/vehicles stowage plus LFORM.
****	Not included in totals.
NOTE 1	There are 6 jettisonable lockers on the catwalks adjacent to the flight deck for the storage of lithium batteries. Coordinate with the CCO if use of these is contemplated.

APPENDIX G. SAMPLE GAMS CODE AND RESULTS

```
GAMS 2.25.092  DOS Extended/C                    07/11/98 11:49:50  PAGE       1
AMPHIB WORST CASE LIFT OPTIMIZATION SCHEDULE


*----------DEFAULTS--------------------------------


OPTIONS
   LIMCOL = 0, LIMROW = 0, SOLPRINT = OFF, DECIMALS = 2
   RESLIM = 1000000, ITERLIM = 1000000, OPTCR = 0 , SEED = 3141;
OPTION MIP=XA;
*-----------------------------------------------------------
       Original: 12/5/97
            Author : LT Eric Williams

       Revised:    4/31/98

       Description: Determine ARGs by Lift Capacity

*--------INDICIES--------------------------------------
SETS
    I    type  /bigDeck, LPD, LSD/
    J    ship  /essex, boxer, peleliu, tarawa, cleveland, ogden,
                juneau, denver, harpersFe, pearlHarb, comstock,
                mountVern/
    K    ARG   /1*4/
    ;
*--------DATA------------------------------------------
TABLE
    TROOP(J,I)  troop base capacity for ship J of type I
                         bigDeck        LPD       LSD
        essex             1631
        boxer             1688
        peleliu           1903
        tarawa            1895
        cleveland                       659
        ogden                           724
        juneau                          682
        denver                          673
        harpersFe                                 405
        pearlHarb                                 406
        comstock                                  402
        mountVern                                 299
        ;
TABLE
     VEHICLE(J,I)  net vehicle capacity for ship J of type I
                        bigDeck         LPD       LSD
        essex            20603
        boxer            20603
        peleliu          23686
        tarawa           23384
        cleveland                     11361
        ogden                         11560
        juneau                        11203
        denver                        13208
        harpersFe                                13944
```

```
          pearlHarb                                18770
          comstock                                 17287
          mountVern                                14555
          ;
TABLE
     CARGO(J,I)  net cargo capacity for ship J of type I
                         bigDeck       LPD        LSD
          essex            92767
          boxer            92767
          peleliu         101649
          tarawa          101649
          cleveland                   29821
          ogden                       32751
          juneau                      31221
          denver                      36387
          harpersFe                              50386
          pearlHarb                              43520
          comstock                                4305
          mountVern                               1303
          ;
TABLE
     P(J,I,K)
                              1      2      3      4
          essex.bigDeck       2
          boxer.bigDeck              2
          peleliu.bigDeck                   2
          tarawa.bigDeck                           2
          cleveland.LPD       1
          ogden.LPD                  1
          juneau.LPD                        1
          denver.LPD                               1
          harpersFe.LSD       1
          pearlHarb.LSD              1
          comstock.LSD                      1
          mountVern.LSD                            1
          ;
*-----------------------------------------------------------
BINARY VARIABLES
    X(I,J,K)  assign ship j of type i to ARG k

VARIABLES
    Z      objective value
    WT     worst case ARG troop capacity
    WV     worst case ARG vehicle capacity
    WC     worst case ARG cargo capacity
    ;
*---------------------------------------------------------
EQUATIONS
    OBJ        maximize worst case capacities
    LIFTT(K)   worst case troop capacity
    LIFTV(K)   worst case vehicle capacity
    LIFTC(K)   worst case cargo capacity
    MINS(J)    each ship used at most once
```

```
GAMS 2.25.092  DOS Extended/C                     07/11/98 11:49:50   PAGE      3
AMPHIB WORST CASE LIFT OPTIMIZATION SCHEDULE

 111       MINI(I,K)   each ARG has only one ship of each type
 112       ;
 113   *-------OBJECTIVE FUNCTION------------------------------
 114   OBJ..
 115       Z =E= WT+WV/(SUM(I,SUM(J,VEHICLE(J,I)))/SUM(I,SUM(J,TROOP(J,I))))+
 116             WC/(SUM(I,SUM(J,CARGO(J,I)))/SUM(I,SUM(J,TROOP(J,I))))+
 117             SUM(I,SUM(J,SUM(K,X(I,J,K)*P(J,I,K))))
 118       ;
 119   *---------CONSTRAINTS-----------------------------------
 120   LIFTT(K)..
 121      SUM(I,SUM(J,TROOP(J,I)*X(I,J,K))) =G= WT;
 122
 123   LIFTV(K)..
 124      SUM(I,SUM(J,VEHICLE(J,I)*X(I,J,K))) =G= WV;
 125
 126   LIFTC(K)..
 127      SUM(I,SUM(J,CARGO(J,I)*X(I,J,K))) =G= WC;
 128
 129   MINS(J)..
 130      SUM(I,SUM(K,X(I,J,K))) =L= 1;
 131
 132   MINI(I,K)..
 133      SUM(J,X(I,J,K)) =L= 1;
 134
 135   MODEL AMPHIB /ALL/;
 136   SOLVE AMPHIB USING MIP MAXIMIZING Z;
 137   DISPLAY WT.L, WV.L, WC.L, X.L;


COMPILATION TIME     =        0.880 SECONDS        VERID WAT-25-092




GAMS 2.25.092  DOS Extended/C                     07/11/98 11:49:50   PAGE      4
AMPHIB WORST CASE LIFT OPTIMIZATION SCHEDULE
Model Statistics    SOLVE AMPHIB USING MIP FROM LINE 136



MODEL STATISTICS

BLOCKS OF EQUATIONS       6     SINGLE EQUATIONS       37
BLOCKS OF VARIABLES       5     SINGLE VARIABLES      148
NON ZERO ELEMENTS       460     DISCRETE VARIABLES    144


GENERATION TIME      =        3.840 SECONDS


EXECUTION TIME       =        3.910 SECONDS        VERID WAT-25-092
```

```
GAMS 2.25.092  DOS Extended/C                  07/11/98 11:49:50   PAGE      5
AMPHIB WORST CASE LIFT OPTIMIZATION SCHEDULE
Solution Report     SOLVE AMPHIB USING MIP FROM LINE 136


               S O L V E      S U M M A R Y

     MODEL   AMPHIB               OBJECTIVE  Z
     TYPE    MIP                  DIRECTION  MAXIMIZE
     SOLVER  XA                   FROM LINE  136

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      1 OPTIMAL
**** OBJECTIVE VALUE               8004.7732

 RESOURCE USAGE, LIMIT          1.350  1000000.000
 ITERATION COUNT, LIMIT      2728      1000000

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 *     Phone 818-441-1565   FAX 818-441-1567
 ************************************************************
Tolerances  (OPTCA) 0    (OPTCR) 0
*** End of XA Messages ********************************



**** REPORT SUMMARY :        0     NONOPT
                             0 INFEASIBLE
                             0  UNBOUNDED

GAMS 2.25.092  DOS Extended/C                  07/11/98 11:49:50   PAGE      6
AMPHIB WORST CASE LIFT OPTIMIZATION SCHEDULE
E x e c u t i o n


----     137 VARIABLE  WT.L                  =      2761.00 worst case ARG troop
                                                            capacity
             VARIABLE  WV.L                  =     48991.00 worst case ARG
                                                            vehicle capacity
             VARIABLE  WC.L                  =    133459.00 worst case ARG cargo
                                                            capacity


----     137 VARIABLE  X.L          assign ship j of type i to ARG k

                            1           2           3           4

BIGDECK.ESSEX             1.00
BIGDECK.BOXER                         1.00
BIGDECK.PELELIU                                   1.00
BIGDECK.TARAWA                                                1.00
LPD    .CLEVELAND                                 1.00
LPD    .OGDEN             1.00
LPD    .JUNEAU                                                1.00
```

```
LPD    .DENVER                            1.00
LSD    .HARPERSFE                                     1.00
LSD    .PEARLHARB            1.00
LSD    .COMSTOCK                          1.00
LSD    .MOUNTVERN                                                 1.00


EXECUTION TIME       =        0.160 SECONDS        VERID WAT-25-092


USER: Operations Research                                  G971215:1528AS-WAT
      Naval Postgraduate School

**** FILE SUMMARY

INPUT      A:\AMPH1.GMS
OUTPUT     A:\AMPH1.LST
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LIST OF REFERENCES

Department of the Navy. "Integrated Amphibious Operations and USMC Air Support Requirements: Annex J. (U) Amphibious Ships" Secret. 15 January 1991.

Military Traffic Management Command Transportation Engineering Agency. MTMCTEA REFERENCE 97-700-2, *Logistics Handbook for Strategic Mobility Planning,* August 1997.

Office of the Joint Chiefs of Staff. Joint Pub 1-02, *DOD Dictionary of Military and Associated Terms*, 23 March 1994.

Office of the Joint Chiefs of Staff. Joint Pub 3-02.2, *Joint Doctrine for Amphibious Embarkation,* 16 April 1993.

United States Marine Corps. FMFRP 1-18, *Amphibious Ships and Landing Craft Data Book.* Headquarters United States Marine Corps. 6 August 1991.

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   Norfolk, VA 23551-2487

9. Commanding General..1
Marine Corps Combat Development Command
Requirements Division
3300 Russell Road, Suite 227
Quantico, VA 22134-5000

10. Commander Amphibious Group 1..1
Unit 25093
FPO AP 96606-5601

11. Commander Amphibious Group 2..1
Unit 60001
FPO AP 96601-6006

12. Commander Amphibious Group 3..1
Box 368201
3985 Cummings Rd, Suite 4
San Diego, CA 92136-5289

13. Commander Naval Surface Forces US Atlantic Fleet (CODE N36)..................1
1430 Mitscher Avenue
Norfolk VA 23551-2494

14. Commander Naval Surface Forces U.S. Pacific Fleet (CODE N30M)..............1
Naval Amphibious Base Coronado
San Diego, CA 92155-5035

15. LT COL John R. Smith...1
I MEF (G-4 SMO)
Box 555300
Camp Pendleton, CA 92055-5300

16. Earl Cruse...1
2361 Jefferson Davis Hwy
Suite 1250
Arlington, VA 22202

17. Prof. Samuel Buttrey, CODE OR..1
Naval Postgraduate School
Operations Analysis Department
Monterey, CA 93943-5101

18. CDR Ronald Brown, CODE OR..1
Naval Postgraduate School
Operations Analysis Department
Monterey, CA 93943-5101

19. LT Eric D. Williams..3
825 Casanova Av. #90
Monterey, CA 93940